DEVELOPMENT OF AN AUTOMATED BRIQUETTING MACHINE

Proponents:

GATMAITAN, Rey Andrew A.

GUANLAO, Tristan Joseph L.

GUTING, Robert John B.

JANAIRO, Caroline Mae J.

Adviser:

Dr. Alvin Y. Chua

DE LA SALLE UNIVERSITY

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ABSTRACT

Briquetting technology is one of the renewable sources of energy that was devised to address problems regarding global warming, energy crisis, as well as solid waste management. Studies like that of Kaliyan and Morey (2009) show that varying the compression parameters during briquetting such as temperature and pressure affects the characteristics of the output briquettes such as combustion performance and durability. On that note, the proponents of this research made that as their motivation which eventually led to the development of an automated briquetting machine prototype for experimentation purposes that could bridge the gap between compression parameters and briquette characteristics.

The fabricated machine used a pressure switch and a band heater for its pressure and temperature variation mechanisms respectively while a PLC was utilized to make the machine's operation automated. Moreover, the machine is composed of a mixing chamber intended for thorough mixing of the feedstock, a cylindrical mold where the feedstock would be briquetted, and a hydraulic system which is responsible for the mold's movements as well as the compression mechanism of the machine. Based on the data collected, the machine demonstrated a tolerance of less than 10% and a return of investment of about 2 years when retrofitted for mass production. Furthermore, the machine is safe to use because it can be operated by simply using the buttons provided in its control panel and has an emergency stop button when emergency arises. In the end, the machine was able to form briquettes at varied pressure and temperature and could be used for future studies regarding briquetting parameters optimization.

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Chapter 1

INTRODUCTION

This chapter discusses the brief background of biomass briquetting including related topics to it. Itis also in this chapter where the problem that was addressed in the research is stated. Furthermore, the objectives to be attained, the significance of the study, as well asits scope and limitations can be seen in this part of the paper.

1.1 Background of the Study

The need for alternative sources of energy has been a sensitive issue for the past years. In the Philippines, the harnessing and utilization of renewable energy has been a significant part of the government's strategy to supply the energy needs of the country (Department of Energy 2011a). To minimize the dependence on imported fuel and to solve problems on energy shortage, considerable efforts have been made to utilize the country's available resources. The use of the several forms of renewable energy such as the geothermal, wind, and solar are studied and researched upon to maximize the benefits that can be harnessed for the country.

As discussed by Cheremisinoff et al. (1980), biomass is essentially a plant material, ranging from algae to wood, in form. However, agricultural residues such as manures, straws, cornstalks, and other by-farming products, are considered to be one of the chief sources of biomass for energy production. The energy content of biomass is relatively uniform, on the order of 9000 Btu/lb (20,890.188 kJ/kg), which is roughly half to two-thirds of coal's heating value. Moreover, there are major advantages of biomass as fuelwhich are as follows: biomass

contains negligible sulfur, generates little ash, and most importantly, is continually renewable. These advantages make it more appropriate to use biomasses as fuel.

As projected by the Department of Energy or DOE (2011b), the biomass supply in the Philippines is expected to reach 323.1 MMBFOE by 2012. These abundant supplies of waste products (coconut husks, corn husks, saw dust, etc.) can undergo processes such as direct combustion, gasification, or liquefication, for energy production. As the world's biggest rice consumers, the increase in rice production in the Philippines went from 5.32 million tons to 12.39 million tons in just thirty years. Accounting 20% of the rice production, rice husk is a processing by-product of the milling processes (Baconguis 2007). However, the physical features of the rice husks make it difficult to store. Also, high volume transportation of this biomass yield high transportation costs, resulting toan uneconomic usage at a place other than the source (i.e., rice mills). With these concerns, new methods for storing, handling, and transporting rice husks have been developed. One of which is in the form of briquettes (Singh &Kasyhap 1985).

Briquetting is the process of transforming a granular or powdery substance into a larger, more convenient size. As discussed by Maglaya&Biona (2010), briquetting increases the homogeneity of the mixture, allowing a more uniform and controlled combustion performance. Also, it greatly helps in the transportation and storage of the fuel. Briquetting can be done using several techniques. One of which is through pressure agglomeration wherein within a confined volume, high forces are applied to a mass of particulate materials to increase its density.

However, before entering the briquette machine, the feedstock must be grinded and be subjected to pre-treatment processes such as the addition of the binding agent (Kaliyan& Morey 2009).

As discussed by Kaliyan& Morey (2009), binders can be a liquid or a solid that forms a bridge, film, matrix, or initiates a chemical reaction to create strong inter-particle bonding. With this, pre-heating or steam conditioning is needed to provide the required heat and moisture that will activate the inherent or added binders. There are different kinds of binders: molasses, starch, phenolic resin, coal tar and others, each with varying binding properties. Their selection is mainly based on the cost, environment friendliness, and on the material of the briquette. The higher the amount of binders added, the higher the briquette durability.

Another factor that is essential and affects the production of the briquettes is pressure and temperature. Under high pressure and temperature, the natural binding components in the biomass (starch, protein, lignin, and pectin) materials are squeezed out of the particles, aiding in the inter-particle bonding. In the case of rice husks, when pressure is increased from 7.8 to 31.2 MPa together with 25% molasses, the durability of the rice husk briquettes also increased from 80 to 95%. One more aspect that is affected by pressure is the shear strength of the biomass briquettes. As the pressure increases, shear strength also increases (Kaliyan& Morey 2009).

The current briquetting industry in the other countries has gone a long way. In Germany, a plantation is situated wherein their machines are automated and can be easily operated. Their production is of large-scale basis and supplies the country with briquettes for energy consumption (RUF Briquetting Machinery 2008). Unfortunately, the briquetting technology in

the Philippines still needs to undergo several improvements. In a research done by Daiwey et al. (2010), a briquette machine was supplied in the Aurora province for their usage. This machine transforms coconut husks into charcoal briquettes and uses cassava or corn starch as the binder. However, all the processes needed in the briquetting such as mixing and molding, are done manually. Also, on another study done by Martin et al. (2008), the briquette machine that they mentioned molds 12 cylinder-shaped briquettes in every extrusion period. To supply the power needed at high pressure compaction, additional manpower may pull down the lever arm.

The automated machines used by the large plantations in the other countries can be made into small-scale and can create a big leap in the current briquetting industry of the Philippines. With automated machines, the variation of process parameters such as the pressure and temperature, will be easier and be more accurate. Also, the briquetting processes will be done in a simpler manner which can result tofewer accidents related to briquetting.

1.2 Statement of the Problem

Variation of the parameters such as temperature and pressure, affects the performance of the briquettes produced. Along with that, the amount of the binding agent used in the production can also be a factor that affects the performance of the briquettes (Kaliyan& Morey 2009). In order to be able to adjust and achieve the parameters and proportions that will yield optimum efficiency and favorable characteristics for the briquette, a machine that allows the alteration of the said factors is needed.

In the Philippines, the briquetting industry is not yet matured compared to the other countries. The Philippines only has manually operated briquette machines that are found in a few areas of the archipelago. Briquette machines are not widely available and those available are not at par with the technology exhibited in foreign regions.

The production of a prototype for anautomated briquette machine can address the problem stated. This prototype can be used for experimentations in order to obtain the optimal parameter settings for a certain biomass briquette. It can be used for the forming and production of several briquettes, utilizing the desired process parameters and using the necessary amount of the binding agent.

1.3 Objectives of the Study

General Objective:

The main objective of the group is to design a small-scale (i.e., for experimentation purposes and not for mass production of briquettes)automated briquette machine.The pressure range will be around 55 kg_f / cm^2 (5MPa) to 95 kg_f / cm^2 (9MPa) and the temperature range is 30°C to 300°C.

Specific Objectives:

1. To implement a controller that will be able to control and adjust the briquetting
2. To implement a monitoring system that displays the status of the critical parameters of the briquetting machine such as the temperature and the pressure

3. To incorporate a sensor in the raw materials' compartment that will monitor the amount or level of raw materials and the binding agent
4. To be able to create rice husk briquettes based on the process parameters determined
5. To be able to include an economic evaluation of the machine

1.4 Significance of the Study

Due to the increasing demand for energy and the constant importation of fuel from other countries, the need for optimization of the use of local energy sources should be given much effort. Production and utilization of alternative energy sources such as briquettes can be of help to address the rising energy needs of the country.

With an automated machine, the control and variation of the parameters of the briquetting processes can be done more accurately and with ease. With that, experimentations for identifying the parameters needed to yield optimum performance of briquettes can be done in the Philippines, not just relying on studies done by other countries. Moreover, with the use of the machine, there will be better homogeneity in the mixture of the biomass and the binding agent, and the safety will be reassured through the monitoring system. Also, with less human interaction, accidents can be minimized.

Using this prototype, further researches on other biomass briquettes can be done. The data obtained in the experiments using this automated machine can be utilized in the industry to create briquettes of high efficiency and quality. This study can also be a head start for the use of automated machines in the country. Other experiments which aim to produce automated

machines appropriate for mass production of briquettes and suited for local use, specifically in rural areas, may soon be initialized.

1.5 Scope and Limitations of the Study

In this research, the automated briquette machine will operate on the pressure range of around 55 kg_f / cm^2 to 95 kg_f / cm^2 and a temperature range of 30°C to 300°C. With that, pressure and temperature ranges aside from the one specified, will not be used. The accuracy of the parameters will be tested through external tools wherein a tolerance of ±10%will be observed. The machine is used mainly for experimental purposes and not for large production of briquettes or for employment in urban or rural areas. The shape of the rice husk briquettes that will be formed are hollow cylinders, accordingly, other forms will not be considered. This shape is chosen because cylinders with a concentric hole gives better combustion characteristics brought about by larger specific area, as discussed by Grover & Mishra (1996).The raw materials that will be used should be properly crushed, sifted, and ready for compression; the thorough mixing of the raw materials and the binding agent will be done by the machine. Except for the manual restocking of raw materials and the harvesting of finished products, the production of the briquettes will be automated. In case of jamming of the raw materials, manual removal and repair must be done.

Chapter 2

THEORETICAL CONSIDERATIONS

In this chapter, the equations which were used for the duration of the research are listed. These equations were used to determine the basic parameters and initial specifications for the design and fabrication of the parts of the briquetting machine.

2.1 Hydraulic System

2.1.1. Hydraulic Cylinder

There are several factors that need to be considered when selecting pre-manufactured and standardized hydraulic cylinders. Such factors include but are not limited to the following: operating pressure of the system, force needed by the cylinder to extend (forward force), force needed by the cylinder to retract (return force), and volumetric flow rate of the hydraulic fluid needed by the cylinder to move forward and to retract. Enumerated below are the equations to be used for calculating some of the said factors.

2.1.1.1 Force

The fluid which pushes the face of the piston produces a force against it. This force is generally equivalent to the force being produced by the hydraulic cylinder and to determine such force, equation 2.1was used (Ramsdale 2006).

$$F = P \cdot A \qquad \text{(Eqn. 2.1)}$$

where:

F = Force, pound (lb)

P = Pressure, pounds per square inch (psi)

A = Cross − sectional area of the piston of the cylinder, square inch (in^2)

2.1.1.2 Piston Rod Speed, Hydraulic Fluid Volume, and Volumetric Flow Rate

The speed of the piston depends on the volumetric flow rate of the hydraulic fluid flowing through the cylinder. Moreover, the volumetric flow rate of the hydraulic fluid entering the piston cylinder is equivalent to the change in volume of the hydraulic fluid per unit time inside it as stated by Industrial Hydraulic Services, Inc. (2007). The mathematical models shown below are the equations that were used to calculate the said parameters.

$$V = \frac{\pi \cdot r^2 \cdot l}{231} \qquad \text{(Eqn. 2.2)}$$

$$v = \frac{231 \cdot Q}{12 \cdot 60 \cdot A} \qquad \text{(Eqn. 2.3)}$$

$$Q = \frac{12 \cdot 60 \cdot v \cdot A}{231} \qquad \text{(Eqn. 2.4)}$$

where:

Q = Volumetric flow rate, gallons per minute (gpm)

V = Volume, gallons (gal)

v = Velocity of the piston rod, feet per second (fps)

A = Cross − sectional area of the piston of the cylinder, square inch (in^2)

l = Cylinder stroke, inch (in)

r = Cylinder inside radius, inch (in)

2.1.1.3 Power

There are two kinds of power to be considered in a hydraulic cylinder namely fluid power and mechanical power. Fluid power refers to the power that a hydraulic fluid can produce or

deliver to the hydraulic cylinder while mechanical power refers to the overall power that was transmitted from the fluid to the cylinder. In general, fluid power is greater than mechanical power because of the friction losses occurring inside the cylinder. Equation 2.5 was used to determine the power that the hydraulic fluid could produce (Industrial Hydraulic Services, Inc. 2007).

$$HP = \frac{P \cdot Q}{1714} \qquad \text{(Eqn. 2.5)}$$

where:

$HP =$ Power, horsepower (hp)

$P =$ Pressure, pounds per square inch (psi)

$Q =$ Volumetric flow rate, gallons per minute (gpm)

2.1.2 Hydraulic Pump

Inchoosing the appropriate kind of pump to be used in a certain hydraulic system, the following characteristics should be determined: pump outlet flow, pump input power, and pump overall efficiency.

2.1.2.1 Pump Outlet Flow

Equation 2.6 was used to determine the volumetric flow rate that a pump could deliver (Industrial Hydraulic Services, Inc. 2007).

$$Q = \frac{n \cdot d}{231} \qquad \text{(Eqn. 2.6)}$$

where:

$Q =$ Volumetric flow rate, gallons per minute (gpm)

$n =$ rotative speed, revolutions per minute (rpm)

d = Pump Displacement, cubic inch per revolution (in^3/rev)

2.1.2.2 Pump Input Power

Equation 2.7 was used to determine the input power needed by the pump for it to operate (Industrial Hydraulic Services, Inc. 2007).

$$HP_{IN} = \frac{Q \cdot P}{1714 \cdot Eff_{OV}} \qquad \text{(Eqn. 2.7)}$$

where:

HP_{IN} = Pump input power, horsepower (hp)

Q = Volumetric flow rate, gallons per minute (gpm)

P = Pressure, pounds per square inch (psi)

Eff_{OV} = Pump overall efficiency, unitless

2.1.2.3 Pump Overall Efficiency

Equation 2.8 was used to calculate the overall efficiency of the pump (Industrial Hydraulic Services, Inc. 2007).

$$Eff_{OV} = \frac{HP_{OUT}}{HP_{IN}} \times 100 \qquad \text{(Eqn. 2.8)}$$

where:

Eff_{OV} = Pump overall efficiency, unitless

HP_{OUT} = Output power, horsepower (hp)

HP_{IN} = Input power, horsepower (hp)

2.1.3. Hydraulic Motor/ Hydraulic Fluid Motor

Whendetermining thespecifications of the hydraulic fluid motor to be used for the hydraulic pump, the parameters listed below should be considered (Industrial Hydraulic Services, Inc.2007).

2.1.3.1 Fluid Motor Torque

According to Ramsdale (2006), equation 2.9 was used to determine the torque that a hydraulic fluid motor could sustain. Alternatively, equations 2.10 and 2.11 could also be used to calculate the fluid motor torque as posited by Industrial Hydraulic Services, Inc. (2007).

$$T = \frac{P \cdot d}{2\pi} \qquad \text{(Eqn. 2.9)}$$

$$T = \frac{HP_{motor} \cdot 63{,}025}{n} \qquad \text{(Eqn. 2.10)}$$

$$T = \frac{Q \cdot P \cdot 36.77}{n} \qquad \text{(Eqn. 2.11)}$$

where:

$T =$ Fluid motor torque, pound · inch (lb · in)

$Q =$ Volumetric flow rate, gallons per minute (gpm)

$P =$ Pressure, pounds per square inch (psi)

$n =$ Fluid motor rotative speed, revolutions per minute (rpm)

$d =$ Fluid motor displacement, square inch per revolution (in^2/rev)

$HP_{motor} =$ Motor rated horsepower, horsepower (hp)

2.1.3.2 Fluid Motor Rotative Speed

Equation 2.12 was used to determine the fluid motor rotative speed as a function of hydraulic fluid volumetric flow rate and fluid motor displacement (Industrial Hydraulic Services, Inc. 2007). Alternatively, equation 2.13 could also be used to determine the fluid motor rotative speed but in this case as a function of frequency and number of windings in the motor poles (Rockis& Mazur 2007).

$$n = \frac{Q \cdot 231}{d} \qquad \text{(Eqn. 2.12)}$$

$$n = \frac{120 \cdot F}{n_w} \qquad \text{(Eqn. 2.13)}$$

where:

$n =$ Fluid motor rotative speed, revolutions per minute (rpm)

$Q =$ Volumetric flow rate, gallons per minute (gpm)

$d =$ Fluid motor displacement, square inch per revolution (in^2/rev)

$F =$ Frequency, hertz (Hz)

$n_w =$ Number of windings in the motor poles, poles

2.1.3.3 Fluid Motor Power

Equation 2.14 was used to determine the power that the fluid motor could produce (Industrial Hydraulic Services, Inc. 2007).

$$P = \frac{T \cdot n}{63{,}025} \qquad \text{(Eqn. 2.14)}$$

where:

$P =$ Output fluid motor power, horsepower (hp)

$T =$ Fluid motor torque, pound $\cdot$ inch ($\text{lb} \cdot \text{in}$)

$n =$ Fluid motor rotative speed, revolutions per minute (rpm)

2.2 Control System

2.2.1 Programmable Logic Controller (PLC)

One of the many types of controllers used in automating various systems (mechanical, electrical, etc.) is a programmable logic controller (PLC). Compared to other controllers, PLCs have an advantage of being able to use the same basic controller for a wide range of control systems. Furthermore, control system modification can be done by modifying the program on the PLC - no need for rewiring, as long as the same inputs and outputs are involved. The result, therefore, is a flexible, cost-effective system that can be used with control systems, which vary quite widely in their nature and complexity (Bolton 2009).

In the case of this research, a PLC acquired from Delta Electronics, Inc. with model number of DVP 32EH00T2 was used. All the inputs in this PLC basically serve as the trigger for the movement of various briquetting machine components. These inputs include three proximity sensors which control the position of the mold, a pressure switch which controls the pressure given by the hydraulic cylinder to the biomass-binder mixture when pressing, and switches which serve as additional control to various steps in briquette production.

Then, the PLC is downloaded with a ladder program that will manage the relationship between the inputs and outputs of the PLC. The outputs of the PLC control the solenoid valves that in turn control the hydraulic cylinder's movement. The electrical diagram and the hydraulic circuit of the briquette machine are show inAppendix A and B, respectively.

2.2.1.1 Input External Wiring

The wiring for the inputs of the PLC is based on the manual. The two types of DC inputs, namely sink and source, differ on how the S/S is connected. The type is determined by the field device or the sensor used. If the field device is a sourcing output (PNP), the PLC input will be a source type and if the field device is a sinking output (NPN), the PLC input will be a sinking type. However, if the type of field device does not match with the PLC input type, the PLC will not be able to read the signal from the field device. The proper wirings according to the field device type are shown below.

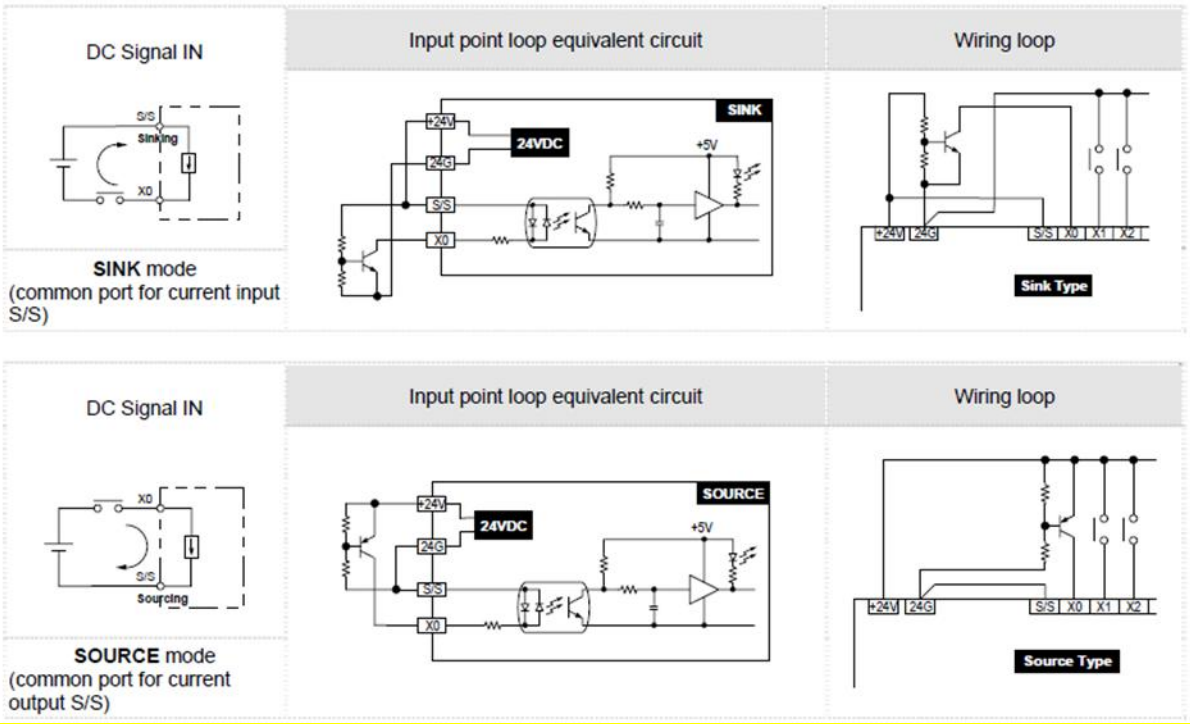


Figure 2.1. PLC input wiring depending on the field device type

(Source: Delta Electronics, Inc, 2006)

2.2.1.2 Output External Wiring

For Delta PLCs, two types of output can be present, relay type outputs or transistor type outputs. Each type has its own wiring diagram that should be strictly followed to avoid damage on the PLC. For the PLC used on this study, the wiring for a transistor type was utilized, as shown on Figure 2.2.

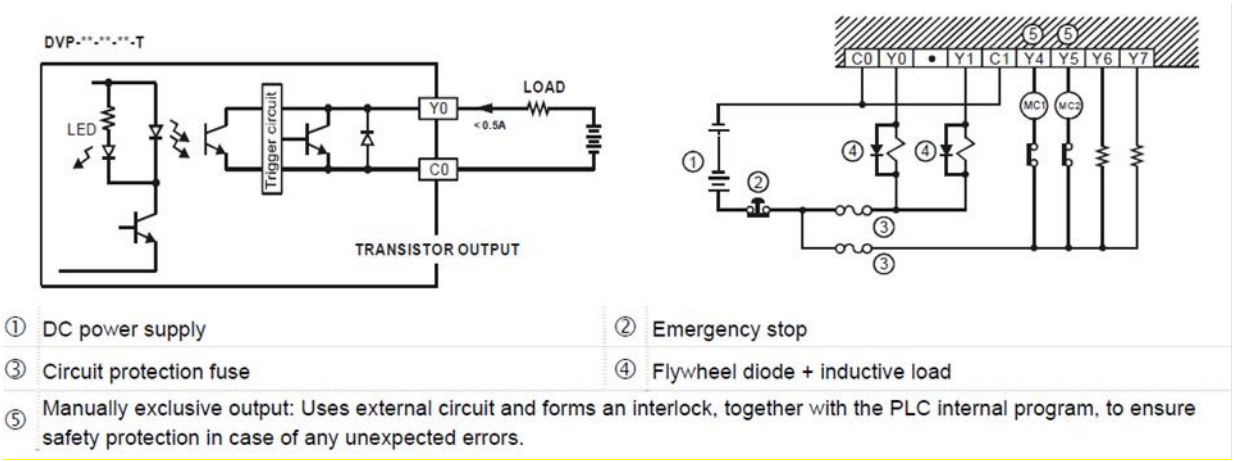

DVP-**-**-**-T
LED
Trigger circuit
Y0
C0
LOAD
< 0.5A
TRANSISTOR OUTPUT
C0 Y0 • Y1 C1 Y4 Y5 Y6 Y7
MC1
MC2
① DC power supply
② Emergency stop
③ Circuit protection fuse
④ Flywheel diode + inductive load
⑤ Manually exclusive output: Uses external circuit and forms an interlock, together with the PLC internal program, to ensure safety protection in case of any unexpected errors.

Figure 2.2. Wiring diagram for a transistor type PLC

(Source: Delta Electronics, Inc, 2006)

2.2.1.3 PLC to Solenoid Valve External Wiring

For the PLC connection to the solenoid valves, solid state relays were used. Since the PLC cannot provide the needed current to operate the solenoid valves, relay switches were utilized to "trigger" the usage of an external power supply. The connections of the solid state relay are shown in Figure 2.3.

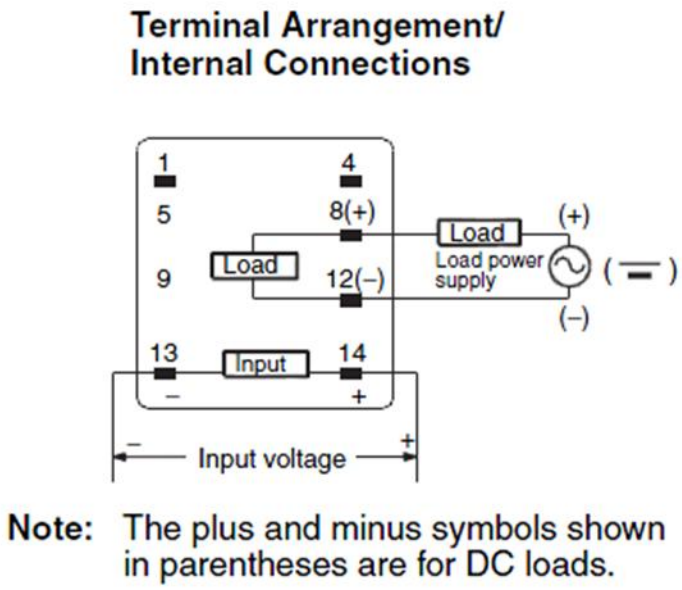


Figure 2.3. Solid state relay wiring diagram (Source: Omron Corporation, 2008)

2.2.2 Ladder Programming

In using the PLC, a number of terms and symbols were used. These drivers and structures used by the group are shown below.

Table 2.1

Devices	Functions
Input Relay	It is an internal memory or storage unit in the PLC corresponding to an external input point. Input relay is used for connecting to the external input signals, making a “0” or “1”.
Output Relay	It is also an internal memory or storage unit in the PLC corresponding to an external output point. Output relay is used for connecting to the external load. The output relay is driven by the contact of an input relay, contacts of other internal devices and the contacts on itself.
Internal Relay	An internal relay does not have any connection with the external. It is an auxiliary relay inside the PLC. Its function is similar with those of the auxiliary relay in the electric control circuit. Every internal relay is similar to a basic internal storage unit and can be driven by the contacts of the input relay, output relay and contacts of other internal devices.
Step	STL instruction controls the transfer of step S, making the writing of the control program easy. If the step program is not in use, Step S can be used as realy M or an alarm point.

Timer	The timer is utilized for timing and has coils, contact and register on it. Whenever the coil is on and the given time is reached, its contact will be enabled. Every timer can have a fixed timing period. Once the coil is turned off, the contact will be disabled, making the present value “0”.
Counter	The counter is utilized for counting. Giving the counter a set of values is needed before using it. The counter also has coil, contact and registers. Once the coil goes from off to on, the counter will consider it as an input of 1 pulse and the present value on the counter will add up or plus “1”.
Data Register	Data Register is used for storing values or all kinds of factors. Every register is able to store a word. On the other hand, double words occupy 2 adjacent data registers.
File Register	File register is utilized for storing data or all kinds of parameters. This is usually used when the data register required for processing the data and value operations are insufficient.
Index Register	This are also 16-bit data registers as other data registers. Index registers can be read and written and can be used in word devices, as a constant for index indication or bit devices.

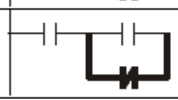
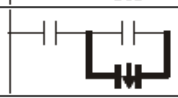
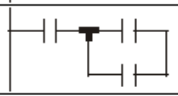
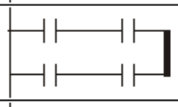
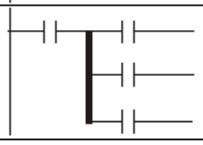
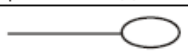
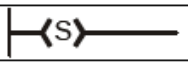
Structure	Explanation
	Normally open, contact A
	Normally closed, contact B
	Normally open in series connection
	Normally closed in series connection
	Normally open in parallel connection
	Normally closed in parallel connection
	Rising-edge trigger switch
	Falling-edge trigger switch
	Rising-edge trigger in series connection
	Falling-edge trigger in series connection
	Rising-edge trigger in parallel connection
	Falling-edge trigger in parallel connection
	Block in series connection
	Block in parallel connection
	Multiple output
	Coil driven output instruction
	Step ladder
	Basic instruction Application instruction
	Inverse logic

Figure 2.4. Ladder programming structure
(Source: DVP – PLC Application Manual)

2.3. Sample Computations

2.3.1 Force

$$F = P \cdot A$$

$P = 1000$ psi
$A = \frac{19.685^2 \pi}{4} = 304.342 \text{ in}^2$

$$\boxed{F = 1000(304.342) = 304242.397 \text{ lbs}}$$

2.3.2 Volumetric Flow Rate

$$T = \frac{Q \cdot P \cdot 36.77}{n}$$

Where: $Q =$ Volumetric flow rate, gallons per minute (gpm)

$$Q = \frac{T \cdot n}{P \cdot 36.77} = \frac{108.664 \cdot 1740}{1000 \cdot 36.77}$$

$$\boxed{Q = 5.14 \text{ gpm}}$$

2.3.3 Power

$$HP = \frac{P \cdot Q}{1714}$$

$P = 1000$ psi
$Q = 5.14$ gpm

$$HP = \frac{1000 \; x \; 5.14}{1714}$$

$$\boxed{HP = 3 \; hp}$$

2.3.4 Fluid Motor Torque

$$T = \frac{HP_{motor} \cdot 63{,}025}{n}$$

$HP_{motor} = 3$
$n = 1740$

$$T = \frac{3 \cdot 63{,}025}{1740}$$

$$\boxed{T = 108.664 \text{ lb} \cdot \text{in}}$$

2.3.5 Fluid Motor Displacement

$$T = \frac{P \cdot d}{2\pi}$$

P =1000 psi

$$d = \frac{2\pi T}{P} = \frac{2\pi(108.664)}{1000}$$

$$\boxed{d = 0.6828 \frac{\text{in}^2}{\text{rev}}}$$

2.3.6 Number of windings in the motor poles

$$n = \frac{120 \cdot F}{n_w}$$

$F = 60$ Hertz for Philippines

$$n_w = \frac{120 \cdot F}{n} = \frac{120 \cdot 60}{1740}$$

$$\boxed{n_w = 4.13 \text{ poles} \sim 5 \text{ poles}}$$

Chapter 3

METHODOLOGY

The research is comprised of 4 essential phases or stages namely the designing of the briquette machine, the fabrication of the briquetting machine, the testing and verification of the briquetting machine's features such as temperature and pressure control, and testing of the operation of the briquetting press using rice husk agro-waste with cassava starch binder as the feedstock.

3.1 Conceptual Design

Figure 3.1shows the conceptual framework that has been developed for the research. The briquette making process begins with the feeding of the raw materials of the to-be-formed briquette in the machine's mixing chamber. In the case of this research, rice husk agro-residue will be used as the feedstock. The mixing chamber will be monitored with the use of a sensor and will have an indicator light that indicates when the biomass level is low.

Inside the mixing chamber, rice husk will be mixed with cassava starch which is the binding agent to be used in the research. It is very important that the rice husk be mixed thoroughly with the starch for it will affect the characteristics of the output briquette. Furthermore, when the feedstock remains stationary inside the chamber, the feedstock will solidify making it unfit for operation. For the design of the mixing chamber, the motor to be installed should be able to handle the weight of the mixing blade plus the weight of the rice husk.

Furthermore, the mixing blade is to be designed such that it can perform thorough mixingof the feedstock and the binding agent.

After passing through the mixing chamber, the mixed rice husk will be transferred to the cylindrical mold or die. While it is accumulating inside the mold, it will be heated up through an installed heater so that the raw materials will become easy-to-compress. A heater display panel will be used to monitor the temperature in the cylindrical mold while a heater control panel will be used to regulate the temperature of the heater (Penton 2011a). The operating temperature that will be employed in the research would range from 30°C up to 300°C.

Subsequent to the heating of the feedstock, the preheated rice husk will now be conveyed to the position directly below the piston that will compress the mixed rice husk into a rice husk briquette. To be specific, the rice husk inside the die will be pressed into briquettes by a hydraulic cylinder with a pressure switch connected to it. The function of the pressure switch is to redirect the hydraulic fluid back to the system's reservoir when the cut off pressure that was set to it is reached. Once the cut off pressure is reached, the pressure switch will signal the PLC to signal the solenoid valve to redirect the hydraulic fluid back to the reservoir. To monitor the amount of pressure being produced by the piston against the feedstock, an analog pressure gauge is connected to it. To vary the amount of pressure that it gives to the feedstock, the control knob of the pressure switch is used. With this, the briquetting machine is given with additional flexibility in terms of processing different raw materials at different pressures. The hydraulic cylinder that was used in the study is a single action piston type with a maximum working pressure of 95 kg_f/cm^2 (approximately 1000 psi or 9 MPa). The other components of the

hydraulic system such as the hydraulic pump, hydraulic fluid, actuators, and reservoir will also be considered in the design of the machine's hydraulic system (Khan n.d.).

The die or mold of the briquetting machine is to be designed in such a way that it is replaceable with different mold sizes and shapes. The machine, which is specifically a prototype, is to be used as an experimental machine, thus it is supposed to have a mold with changeable output briquette shapes and sizes. Upon having compressed the rice husk, the final step is the discharging of the pressed briquette.

Overall, the actual mechanical parts of the briquetting machine will either be designed using computer software programs or a manufacturer's catalogue, or be designed based on consultations from experts. Simultaneous with the designing process, the search for manufacturers of the needed machine components is going on. Those needed machine parts that are readily available in the market will be purchased while those that are not readily available will be asked to be fabricated. Sensors, logic controls, and computerized monitoring will be integrated in almost every component of the briquetting machine so that the user is able to witness what is happening inside the machine and is able to manipulate easily the briquetting operation parameters based on his/ her preference.

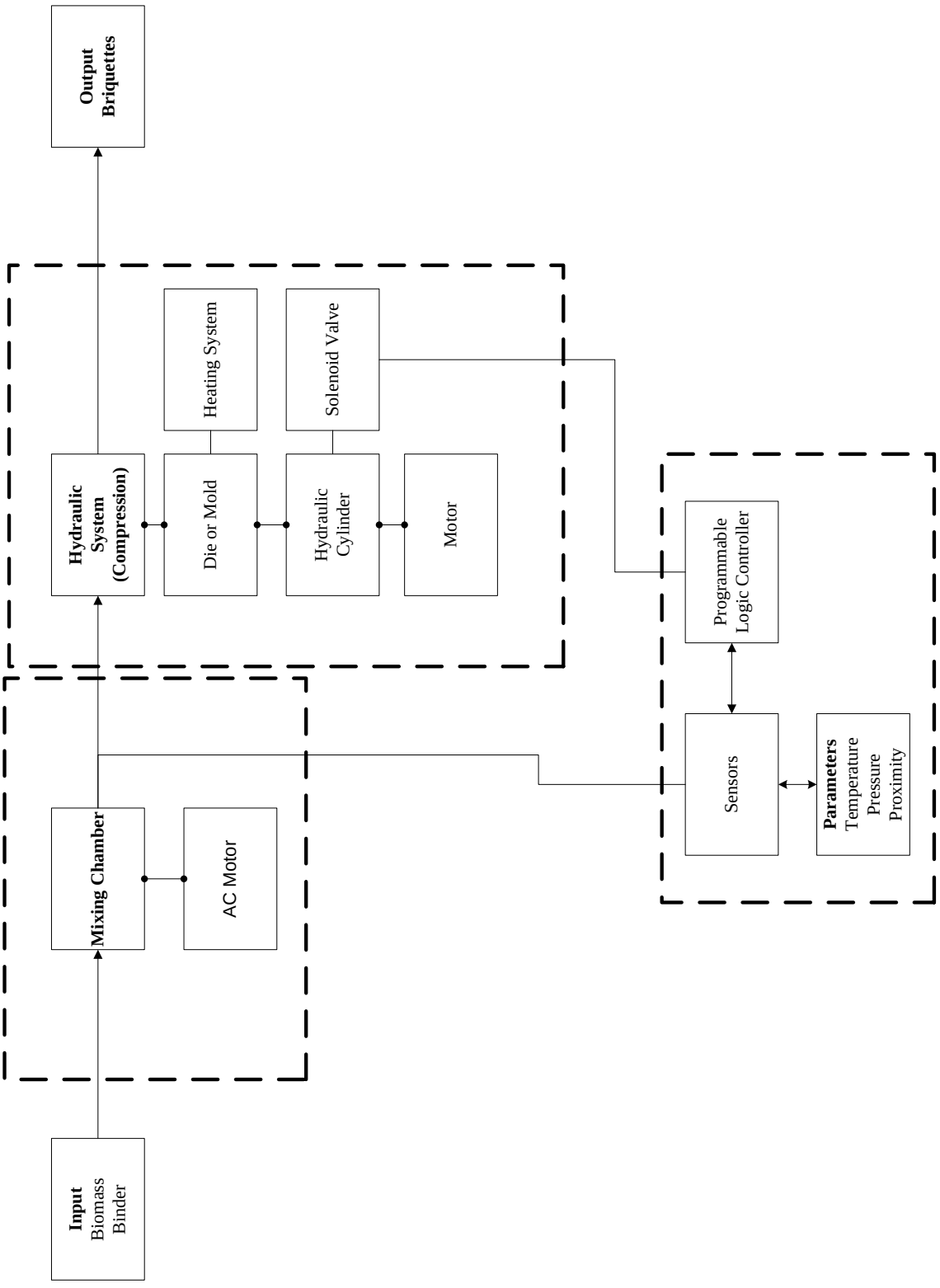


Figure 3.1. Conceptual Framework of the Study

3.2Phase 1: Briquetting Machine Design Phase

This phase of the research is further divided into two sub-phases which are the design of the mechanical system and the design of the control system. On one hand, the mechanical system of the machine is composed of its mechanical framework, hydraulic system, and heating system. On the other hand, the control system of the machine is composed of mainly of sensors, switches, wiring, and ladder program. On that note, commercially and readily available computer-aided design, simulation, and programming software programs were used during this design phase.

To be specific, Solidworks 2012 was used to design and simulate the mechanical framework of the briquette press while WPLSoft 2.20 was used for the control system. However, as for the hydraulic system as well as the heating system, the design process simply involved simple calculations of the technical parameters that would be used to define or describe the systems mentioned.

Fundamentally, a particular design or automation plan will be approved or appraised acceptable based on cost, (relative) ease of fabrication, load handling capacity, factor of safety, feedback time, (relative) ease of programming, size, and design practicality.

3.2.1 Mechanical System

This section includes the design process of the mechanical system of the briquette press under study which includes the following: [1] mechanical framework (i.e. stand, mixing chamber, mixing blade, mold, etc.), [2] hydraulic system (i.e. solenoid valve, relief valve, pump,

pump motor, piston cylinder, etc.), and [3] heating system (i.e. band heater, thermocouple, temperature controller, etc.).

3.2.1.1Mechanical Framework

First, the individual mechanical parts of the machine's framework such as the mixing chamber, cylindrical mold,die, and ram, etc. were designed using Solidworks 2012. Some of these mechanical parts were patterned based on the paper of Fule et al. (2010) entitled, "Automated Briquetting Machine". Nevertheless, in general, the designs of the individual parts were designed based on the reference materials obtained through research.

Afterwards, the initial design for each of the briquetting machine parts were subjected to stress simulations and other essential machine design simulations such as factor of safety, variable loading, and strain simulations. Designs were reviewed and eventually were accepted based on the aforementioned rubric.

If a certain part does not meet the set design standards, it will undergo a redesigning process and the redesigned part will then undergo the same set of stress and machine design simulations. When all the individual designs of the machine's framework have passed all the simulations and were regarded as up-to-standard, the assembly of the individual mechanical parts of the machine's mechanical framework will then proceed.

Upon having completed the assembly of the framework, stress and machine design simulations were again made but this time the loading was intended for the whole assembly

(combined loading). If the assembly is seen to possess any form of flaw during the combined loading simulations, the assembly will undergo modification until it becomes an acceptable assembly design. Once all simulations have been done to the assembly of the mechanical framework of the to-be-fabricated briquetting machine and have passed the set rubric, the design of the hydraulic system of the machine will be next.

The figure below, Figure 3.2, shows the course of the design process of the mechanical framework of the briquette press including its assembly. Furthermore, the approved mechanical framework assembly of the to-be-fabricated machine is shown in Figure 3.3 while the illustrations of the individual parts can be seen in Appendices A & B.

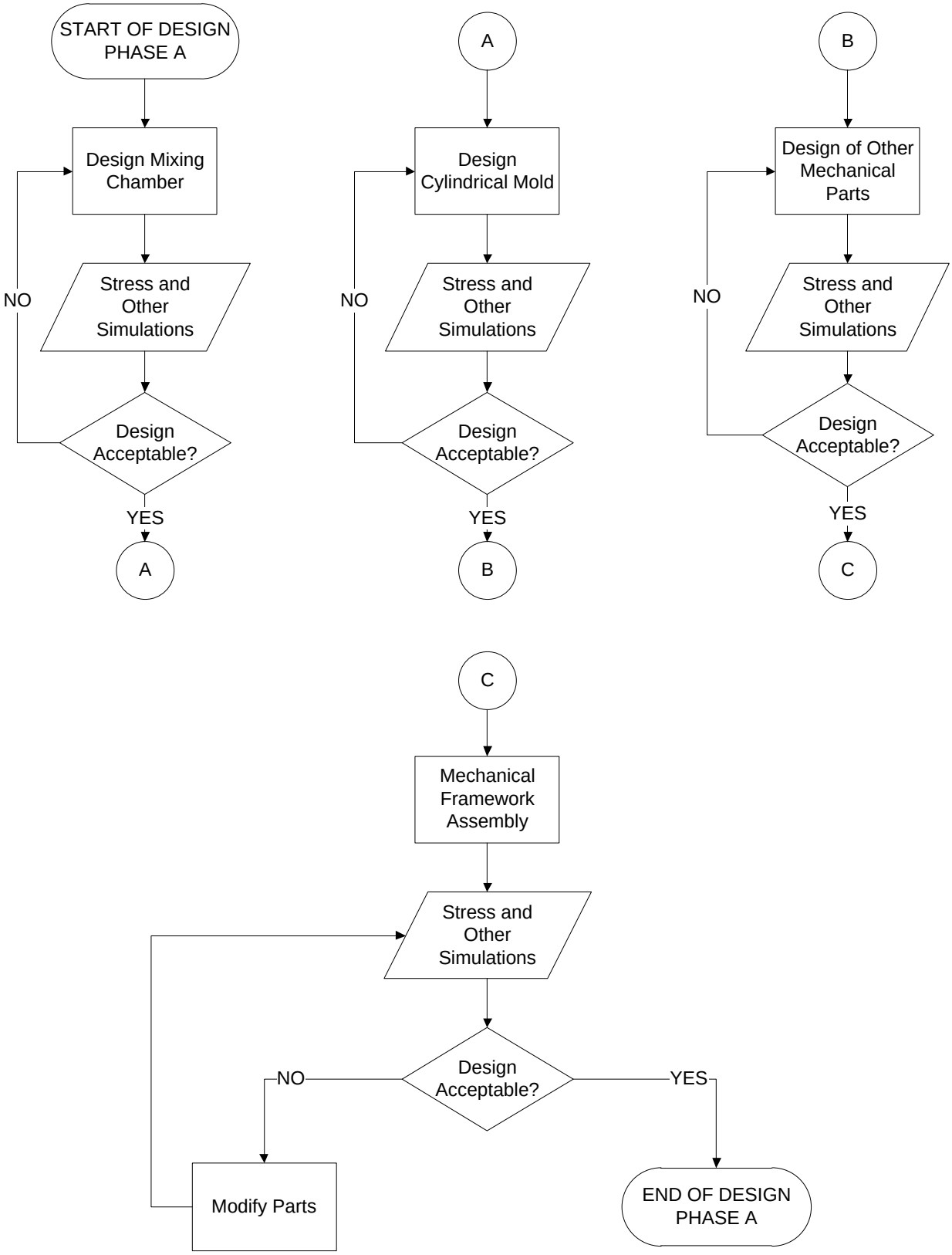


Figure 3.2. Briquette Press Mechanical Part Design

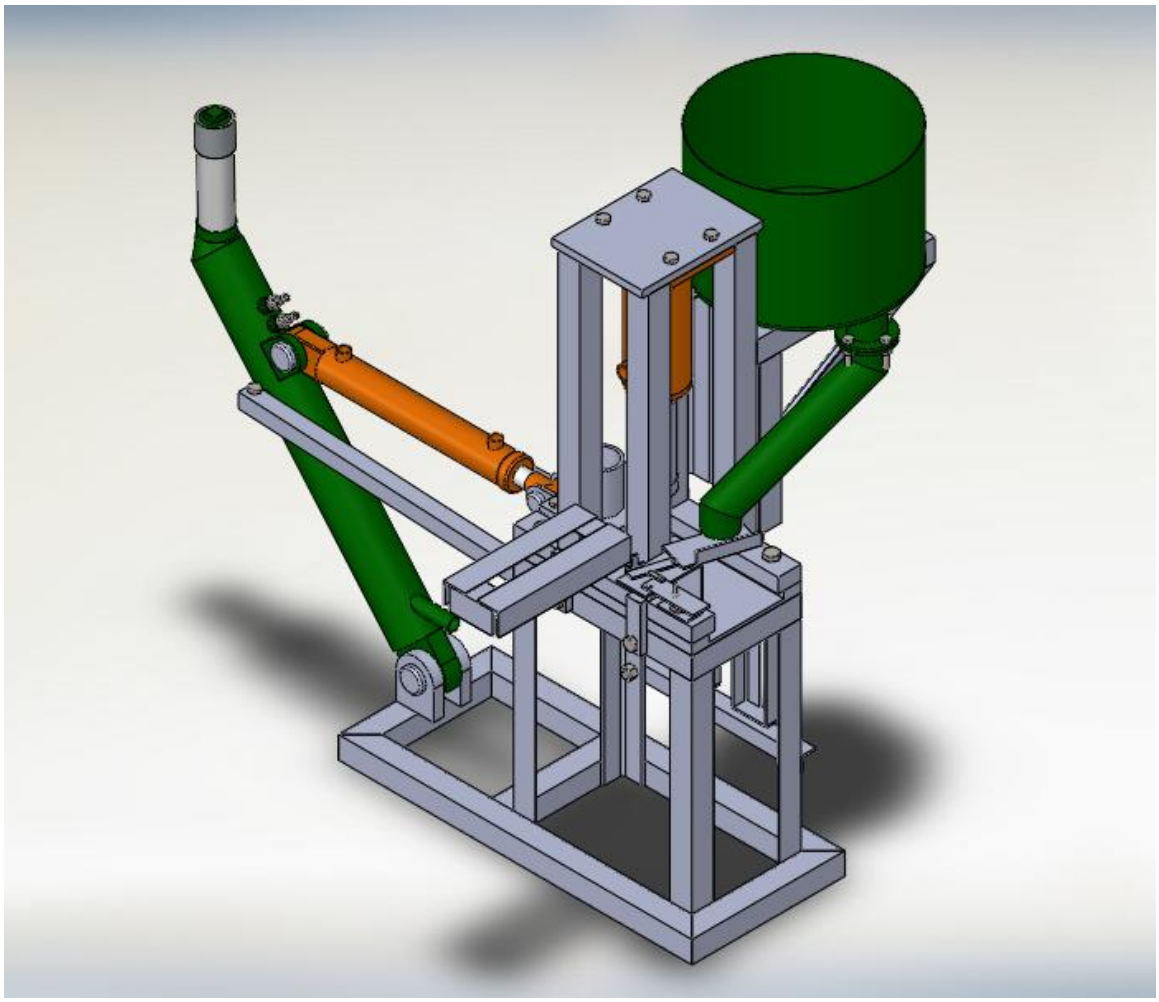


Figure 3.3. Approved Mechanical Framework Assembly

3.2.1.2 Hydraulic System

Aside from the mechanical framework of the briquette press, the machine's mechanical system is also comprised of a hydraulic system which is responsible primarily for the movement of the cylindrical mold as well as the application of the required pressure against the biomass, in other words, the pressing proper itself.

Thedesign process of the hydraulic system of the briquetting machine is very much different from that of the design process of its mechanical framework.At one point, the design of the hydraulic system no longer underwent any computer-aided designing and simulation.Basically, the design processinvolvedtwo main considerations: [1]theselection of appropriate hydraulics equipment for the system such as the pump, solenoid valve, piston cylinder, hoses, etc. based on the(a) calculations made, (b) design of pre-existingmanually-operated briquette machines, and (c) availability of supplies, and [2]the mounting and connection of these equipment in accordance with the machine's overall operation. Furthermore, the design of the briquette press' hydraulic systemwas based on the two primary sources which are published reference materials (i.e.journals, books, manufacturer's catalogues, and user's manuals)and consultations from experts in hydraulics (i.e. thesis adviser, professors, and manufacturers).Nonetheless, the approved hydraulic system circuitry of the machine is depicted in Appendix G.

3.2.1.3 Heating System

Another component of the briquette machine which is under the mechanical system bracket is the heating system. As the temperature aspect of briquetting is an indispensable factor, it is of great importance to choose the right device to attain the desired temperature for the machine's operations. With that in mind, potential manufacturers were looked into the internet, directories, and catalogues, taking into consideration the different heaters they offer. After having identified the manufacturer with the most versatile list of the needed equipment, the proponents of the research consulted with themaiming to identify the most suitable design of heaterthat is in line with their objectives.

Having said that, the band heater-type of heater was chosen for the research primarily because it can be attached to the system easily without risking too much heat loss. With its cylindrical hollow shape, it envelops the mold and transfers heat to the feedstock through conduction. A thermocouple is attached to the band heater to monitor its temperature, ensuring that what is being given off by the heater is within the threshold of the preferred parameter. With the desired maximum temperature of 300°C, the wattage and voltage of the heating system was determinedand was eventually manufactured by the chosen supplier which was RKRS Industrial Heater. Figure 3.4 is a picture showing the chosen and manufactured heater that was utilized in the study.

Figure 3.4 Band Heater

Following the heating system, the planning, design, and programming of the controls components and the monitoring system of the machine will be next inline.

3.2.2 Control System

The initial step in the design of the control system that was employed in the briquetting machine is to establish what parameters or analog signalsare to be monitored and controlled. Such scheme may be referred to as Control SystemAlgorithm Planning.

At this point, logic operationsof the machine are to be defined. For example, when the pressure exerted by the hydraulic cylinder against the feedstock is too highor when the mixing chamber runs out of feedstock,what should be the response of the machine.The design of the control system waslikewise evaluated using the same rubric aforementioned.

Selectionof the sensors to be used for the actual machine will go after the planning of the control system. In this regard, it is important to know what type of sensors should be used with different forms of analog signals. A pressure sensor which senses pressure signals, for example, is different from a temperature sensor which senses temperature signals. Moreover, sensors used for solids (e.g. piezoelectric sensors) are different from sensors used for fluids (e.g. digital air pressure sensors).

Subsequent to the selection of sensors is the identification of the external wiring of the controls components of the press based in their manuals. As have been mentioned earlier, the PLC that was used in this paper was a Delta PLC with model number of DVP 3200EHT2. Its wiring requirements, along with the inputs and outputs, can be found in its manual which is in effect can be seen in Appendix H of this paper.

Moving on, the planned algorithm of the control system was converted into a machine code and was then programmed into the PLC using the WPLSoft 2.20 software.However, before engaging the controls into actual practice, computer simulations using the said software were carried out in this step mainly for the purpose of verification and debugging.After having verified and debugged the program, the control system wasthen tested whether rit is responding according to the desired response of the study. In the event when the control system does not responding as per the standard set in the study, reconfigurations are to be done to it until such time that it works with an acceptable quality.After accomplishing such test, Sub-Phase B of the briquette press'design phase is already done.

To be more visual, Figure 3.5 below portray the control system of the machine was designed as well as programmed.

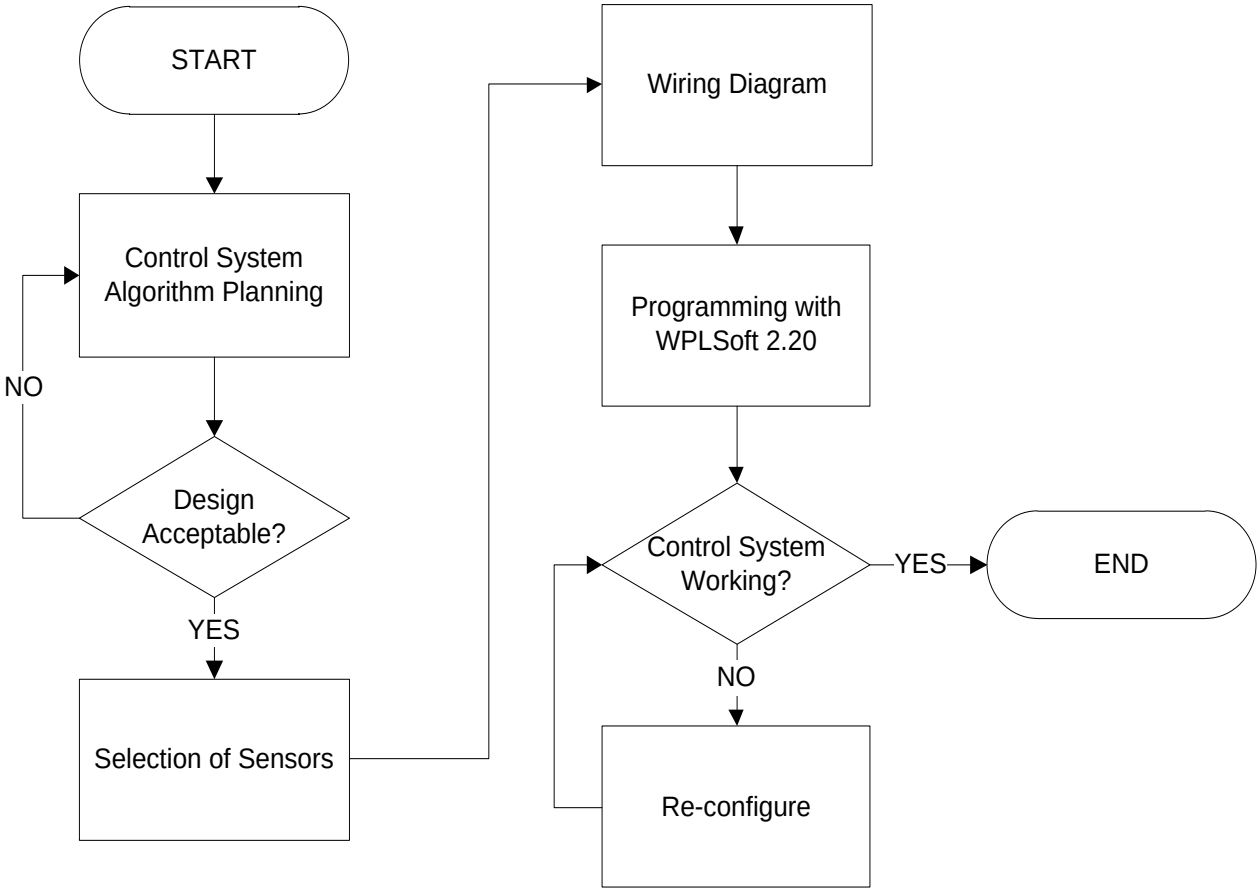


Figure 3.5. Briquette Press Digital Part Design

3.3Phase 2: Briquetting Machine Fabrication and Assembly

This stage of the research marks the start of the construction of the briquetting machine prototype. Depending on the accepted blueprint, the materials with their corresponding quantities and dimensions will either be purchased or will be obtained throughoutsourcing (i.e. by recycling, by borrowing, or by having the materials becustom-built by a certified manufacturer).

Essentially, all the accepted designs that have been generated from the previous steps will now be realized into actual parts which will then be assembled later on. All the important components of the machine such as the mechanical framework, hydraulics system,

heatingsystem, control system, and electrical parts will be actualized and later on be integrated all together to form the overall prototype of the automated hydraulic briquette press.The table below, Table 3.1, shows how the proponents of this study outsourced or actualized the individual parts of the machine to form the overall prototype.

Table 3.1. Method of Acquisition per Machine Component

Qty.	**Component**	**Method of Acquisition**
1	1) Machine Package	1) Purchased from Tipontipon Welding Shop
1	2) Heating System	2) Purchased from RKRS Industrial Heater
1	3) Pressure Switch	3) Purchased from Ace Hydraulics Enterprises
3	4) Proximity Sensors (Metal)	4) Borrowed from DLSU
1	5) Proximity Sensor (Presence)	5) Purchased from E-Gizmo
1	6) Dial-Type 10 MPa Pressure Gauge	6) Purchased from Sky Electrical and Pneumatic Control Center
1	7) Programmable Logic Controller	7) Borrowed from DLSU
4	8) Solid-State Relay Switches	8) Purchased from E-Gizmo
4	9) Switches (Push Button, Toggle, etc.)	9) Purchased from RodcellElectrical Control Center and Deeco
5 L	10) Hydraulic Oil	10) Purchased from Jomac's Trading
1	11) Solenoid Valve	11) Borrowed from DLSU's previous thesis
n/a	12) Other Electrical Auxiliaries	12) Purchased from E-Gizmo and Deeco

Note that the machine package from above includes primarily of the following: machine framework, hydraulic system, mixing chamber, guide tube, dial-type 15 MPa ($150kg_f/cm^2$)

pressure gauge, pump, 3-hp pump motor, ½-hp mixing blade motor, belt, pulleys, hoses, bolts, nuts, etc.

When the briquettingmachine has already been constructed, a test run without the feedstock yet will be done.The machine will be noted if it is working or not. In the event that the prototype does not work, troubleshooting will be done to the briquetting machine until such time that it operates. In terms of the acceptability of the fabricated prototype, a new determinant will be used to verifywhetheritis acceptable or not.Basically, the prototype will be accepted if the technical specifications that it manifestssuch as maximum operating pressure, tolerance, input power requirement, briquette diameter, weight, etc. (with tolerance being the core determinant) meet tolerably or is at par with the computed or expected technical specifications of the prototype based on either computations or ratings of the individual parts.

The following figure, Figure 3.6, is the step-by-step procedure of the second phase of the research which is fabrication and assembly.The output of this phase of the research is basically the actual machine prototype.

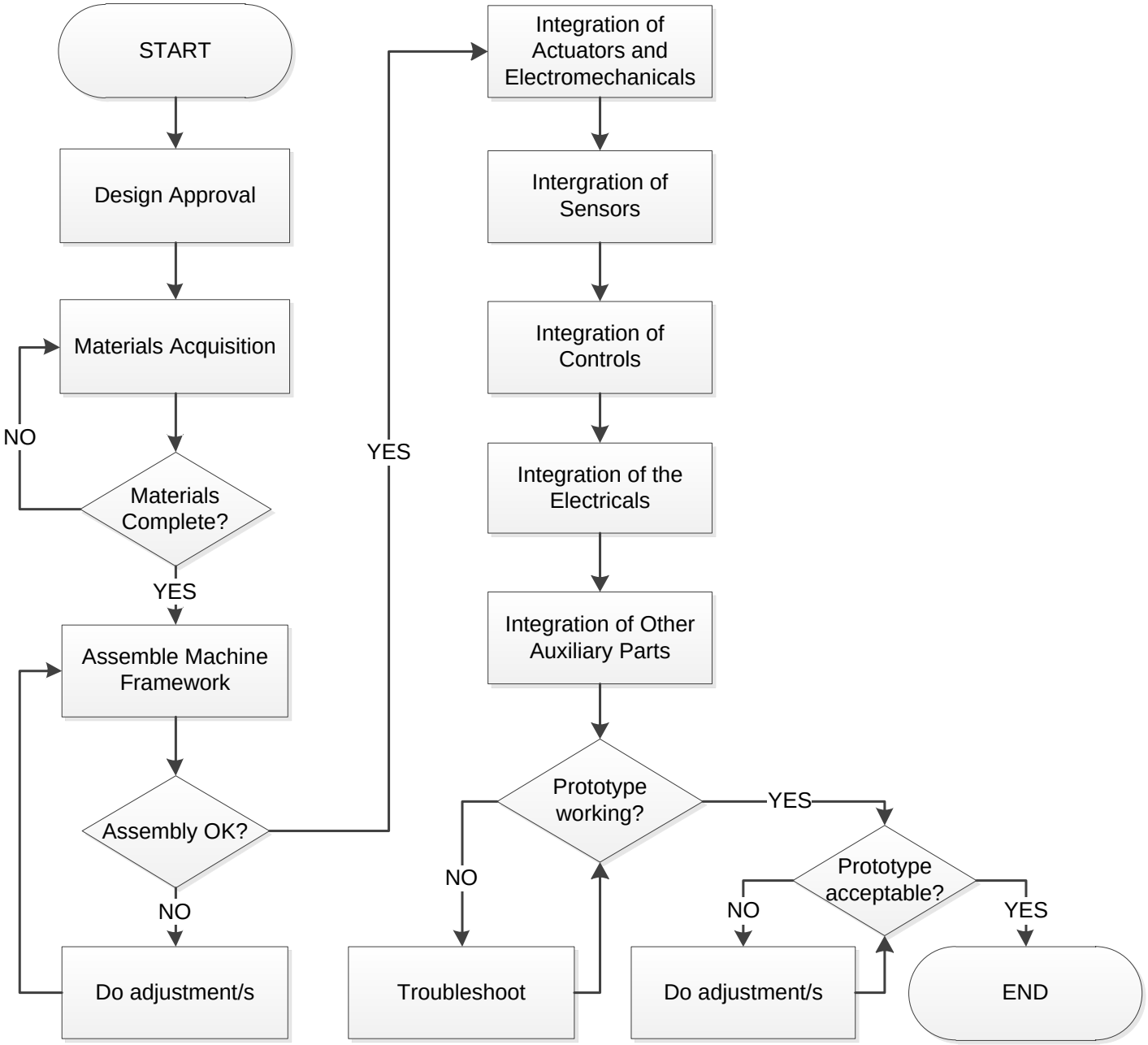


Figure 3.6.Flow of the Briquette Press Fabrication and Assembly

3.4 Phase 3: FeaturesTesting and Verification of the Briquetting Machine

Aside from the to-be-conducted test run in the 2nd phase of the researchwhich is intended to merely check whether the prototype is working or not, testing and verification of the machine's functionalities will be carried out in this 3rd phase of the research.In this step, the features of the automated briquetting machine such as pressure and temperature control and monitoring were validated manually using appropriate tools and measuring instruments. Also, experiments to determine the value of the machine tolerance which is, as have been mentioned, the core determinant for the acceptance of the prototype were performed.

3.4.1 Testing and Verification Overview

The testing scheme primarily involved the measurement of directly measureable analog signals (e.g. temperature and fluid pressure) through manual means and computing for the values of the parameters (e.g. horsepower requirement and pressure exerted on the mold) through equations. In due course, this testing scheme would be able to determine some of the technical specifications of the fabricated prototype.

On the verification part, the directly measured (or calculated) values of some parameters such as temperature and pressure were compared with the values of those parameters displayed on the built-in gauges of the machine or measuring instruments. For an instance, the temperature monitoring of the machine will be verified by comparing the displayed value of the temperature to the manually and directly measured temperature of the machine part where the heater is situated. If any inconsistency in the machine is seen, adjustment/s will be made as well as

verification/s. Evidently, the parameters that are being displayed on the gauges are the ones to undergo verification process.

Through statistical analysis of the data generated from the tests, the tolerance of the machine features was then defined. Overall, a machine tolerance of ±10% would be observed. In the event that the computed tolerance is not at par with the set tolerance, adjustment/s will be made for it is considered to be a form of inconsistency. The general overview on how phase 3 of the research will go about is demonstrated in Figure 3.8. As can be seen, Figure 3.8 is a simple example of the features testing and verification phase with pressure and temperature being the analog signals to be measured, compared, and analyzed.

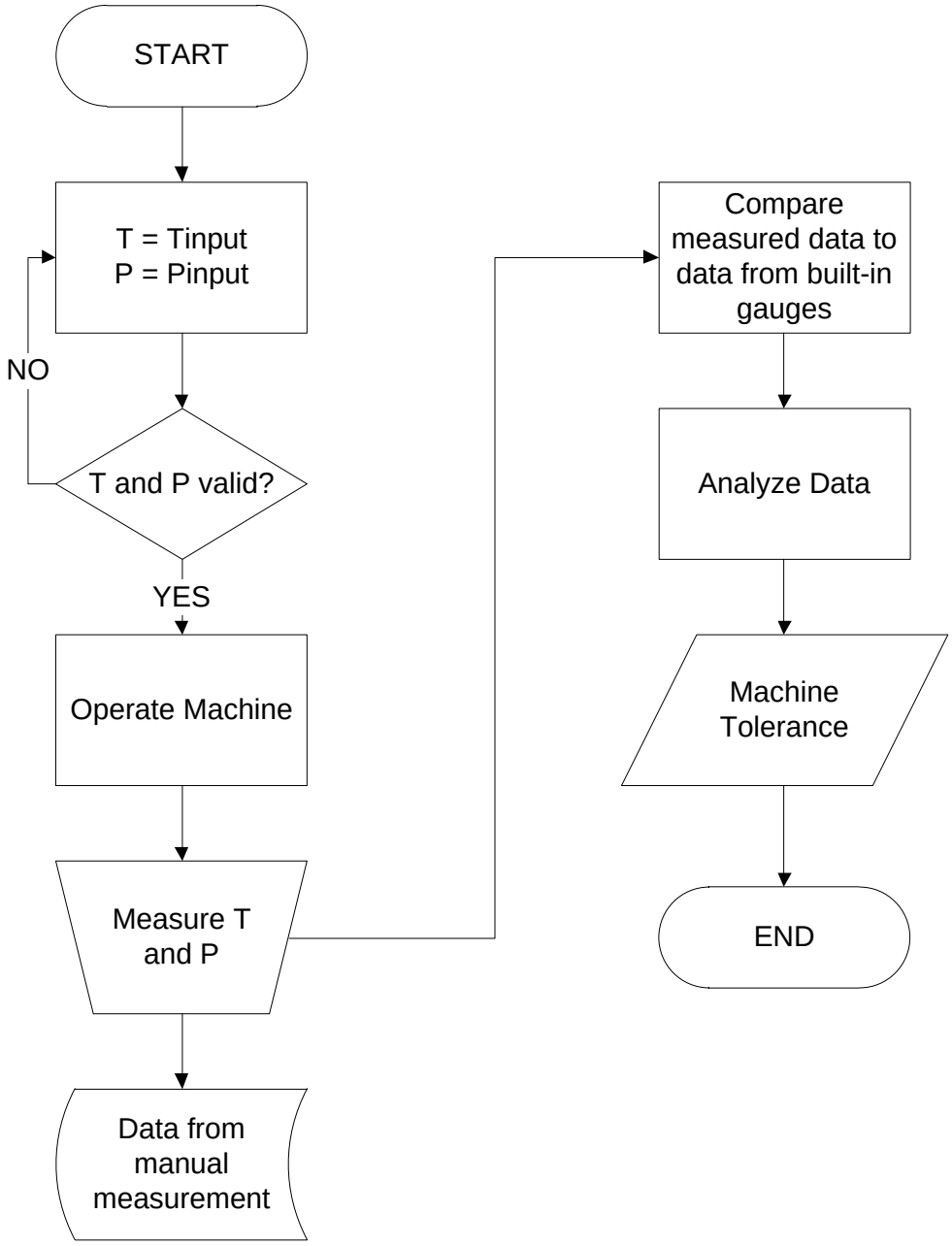


Figure 3.8. Sample Run of the Features Testing and Verification Phase

3.4.2 Verification of the Accuracy of the Band Heater

To manually test whether the temperature that is said to be being supplied by the band heater to the cylindrical mold is accurate, a K-type pocket thermocouple was used. The thermocouple was attached to the band heater as illustrated in Figure 3.9.The readings from the

pocket thermocouple as well as the built-in thermocouple of the band heater were taken simultaneously and were recorded for further analysis. The experimentation was done three times, wherein for each trial, the temperature readings were taken every 10°C. The initial setting of the band heater was the one closest to the room temperature which is 30°C, while the peak temperature setting was 300°C, which is also the maximum operating temperature of the band heater. Despite that there were noticeable differences between the values of the readings of the built-in thermocouple and pocket thermocouple, these differences were kept under ±5% margin of error.

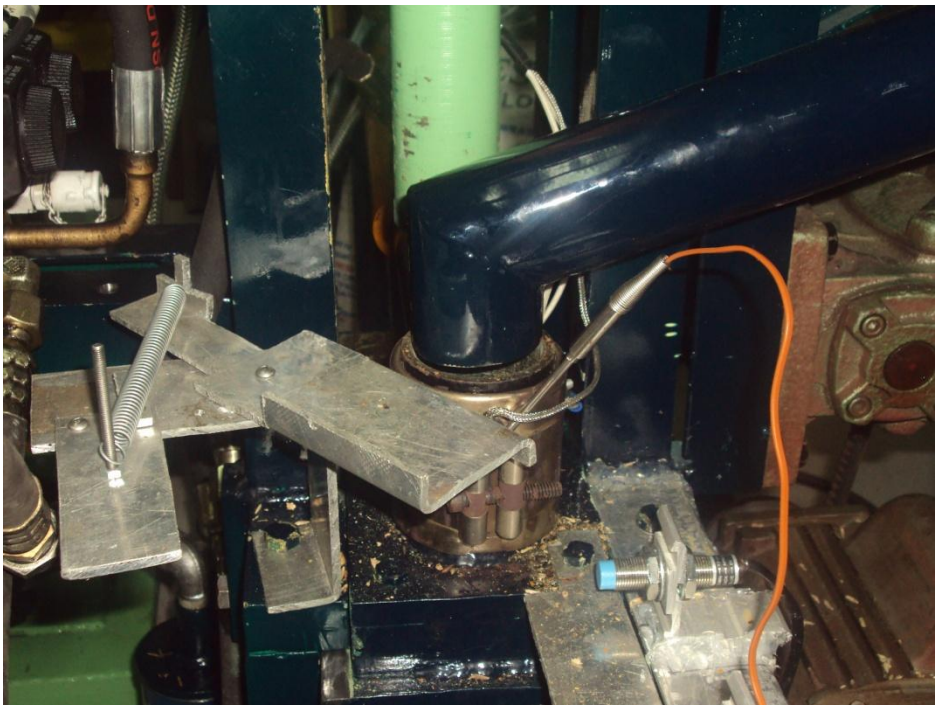


Figure 3.9. External thermocouple attached to the band heater

3.4.3 Verification of the Accuracy of the Pressure Switch

To begin with, the pressure switch that has been acquired for the study has a vague metrological graduation which cannot be understood even with the aid of the proponents'

consultation with its vendor since there is no available user manual for the said component. Hence, the proponents of this research eventually decided to set their own convention for the pressure switch based on the minimum and maximum operating pressure of their machine. With that, the circumference of the pressure switch was divided into 4 quarters, namelythe north, east, west, and south quarters as shown in the Figure 3.10 underneath. After a few trials, it has been found out that each quadrant or quarterof the pressure switch signifies an increase of around 5 kg_f/cm^2.

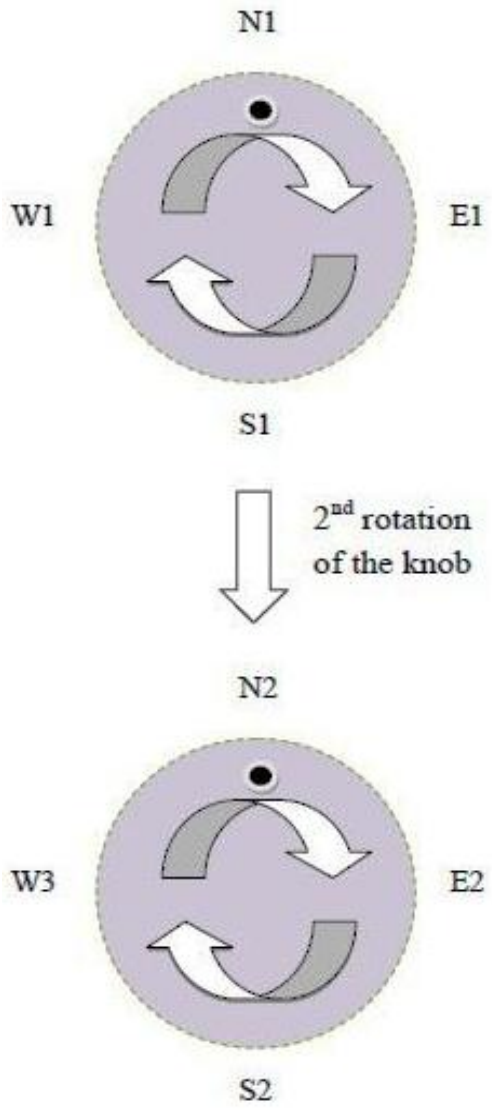


Figure 3.10. Pressure Switch Convention

To proceed with the manual verification of the pressure switch's accuracy, two Bourdon gauges were used.Pressure gauge 1 (PG1) has a maximum pressure of 150 kg_f/cm^2 and islocated or mounted before the solenoid valve while pressure gauge 2 (PG2) has a maximum pressure capacity of 100 kg_f/cm^2 and is located or mountedright before the vertical hydraulic cylinder.The experiment is done by recording the readings of the two pressure gauges for every trial of the pressure switch while increasingthe compression pressure by an increment of 5 kg_f/cm^2per trial. This implies that the dial of the pressure switch is being rotated from quadrant to another in a clockwise direction, until it reaches the 'north four' quadrant (N4) which is the maximum pressure of in the study with an equivalent numerical value of 95 kg_f/cm^2.

3.4.4 Verification of the Control System Circuitry

The external wiring of the PLC as well as its inputs and outputs needs to be verified before engaging into operation because errors in external wiring could critically destroy the PLC or worse, the whole control system itself. Thus, to avoid such scenario, all components of the control circuit were tested to ensure that they are working properly prior toactual experiments.

The verification of the control circuit starts with double-checking physically the actual wiring that has been done to the controls component of the system with the indicated correct wiring written in the manual. The moment when the external wiring has been verified as correct, another test is still to be carried out but this time with the PLC turned on.

To be a little bit more concrete, take the proximity sensors used in the study as an example. The proximity sensors that were used in the study are sink-type sensors. With that, the

PLC hasto be set to a sink-type DC input configuration as well. Therefore, the S/S port of the PLC should be connected to its +24V portwhile the 24G port should be connected to the input ports (X's). To verify whether the wiring is correct, a multimeter, also called a VOM, was used to measure the voltage between the 24G port and the input ports. If the reading in the VOM (in voltmeter mode) flashes a value of approximately 24 VDC, then the connection is deemed to becorrect; otherwise, it is considered incorrect. Likewise, the connection of the sensors was also verified using this method.

The next thing to verify after the input external wiring iswhether the output port detects an input signal, or in other words whether the output signal is triggered by input ones.To do so, a very simple input-output ladder program, as shown on Figure 3.11, was downloaded to the PLC.

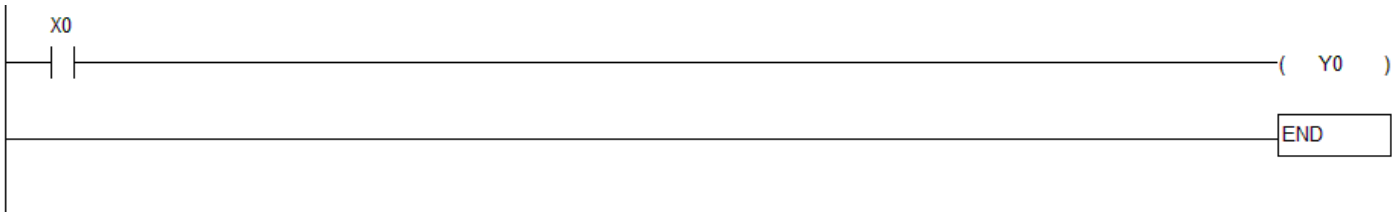


Figure 3.11. Program used in verifying the output signal

The test for the output goes as follows. While maintaining a signal on the output port Y0, the voltage across the common port and the output ports (Y's) was measured. Similar to that of the input, if the voltmeter reading acrossthe common port and output ports flashes a value of approximately 24 VDC, then the connection is considered to be correct, otherwise, it needs rewiring for it is incorrect. Further verification was done to the control system by repeatedly

turning on and off the inputs on the program while simultaneously taking note if the output port will behave as programmed.

3.5Phase 4: Briquette Press OperationTesting

Prior to the operation and performance testing of the fabricated briquette press, the rice husk agro-waste and cassava starch binding agentwere obtained. More importantly, preparation of the rice husk agro-waste and cassava starch as feedstockwas done before it was fed into the machine.According to Grover and Mishra (1996), for agro-residues and mill-residues, the unit pre-processing or pre-treatmentto be done prior to densification or briquetting include sieving and crushing of the dried agro-waste. Displayed in the diagram of Figure 3.12 is the process flow diagram developed in the study on how to compact rice husk biomass into briquettes.

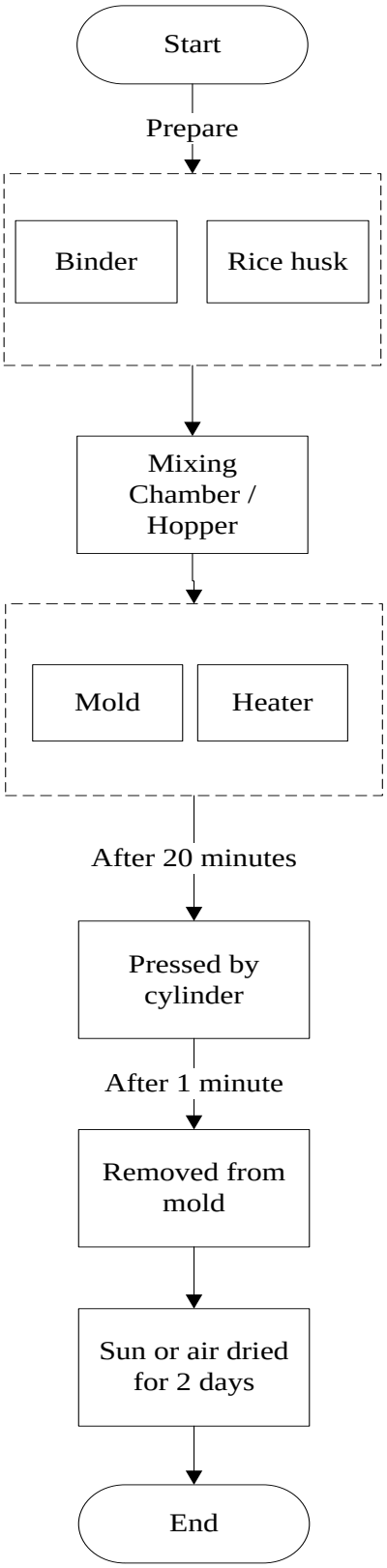


Figure 3.12. Briquetting Process Flow Diagram

3.5.1 Preparation of the Feedstock

The feedstock that will be loaded into the mixing chamber of the fabricated briquetting machine is a mixture of ground rice husk biomass and cassava starch that was made into a paste. To prepare this, both the rice husk biomass as well as the cassava starch needs toundergo a pre-processing before they could be mixed together as a feedstock.

First in the line is the pre-processing of the raw rice husk agro-waste into ground state. To do so, it involves grinding of the raw rice husk into smaller particles with the help of a household blender.Physically, the ground state of the rice husk is supposed to appear as nearly pulverized but not exactly pulverized. The reason for grinding is fundamentally for better and easier compaction. More often than not, the rice husk biomass which can be obtained from the local market has a low bulk density.In the case of this research, one briquette sample contains about 36.65 % rice husk biomass by weight which is approximately equal to 70 grams. The images below, Figure3.13, illustrate the ‘before grinding’ and ‘after grinding’of the rice husk.

Figure 3.13. Rice Husk Agro-Waste Pre-Processing

Upon having a significant amount of ground rice husk ready for mixing, the pre-processing of the cassava starch paste, which will act as a binding agent, will then follow. The following pictures in Figure 3.14 and Figure 3.15 show the ingredients and apparatuses needed to create the binder respectively.

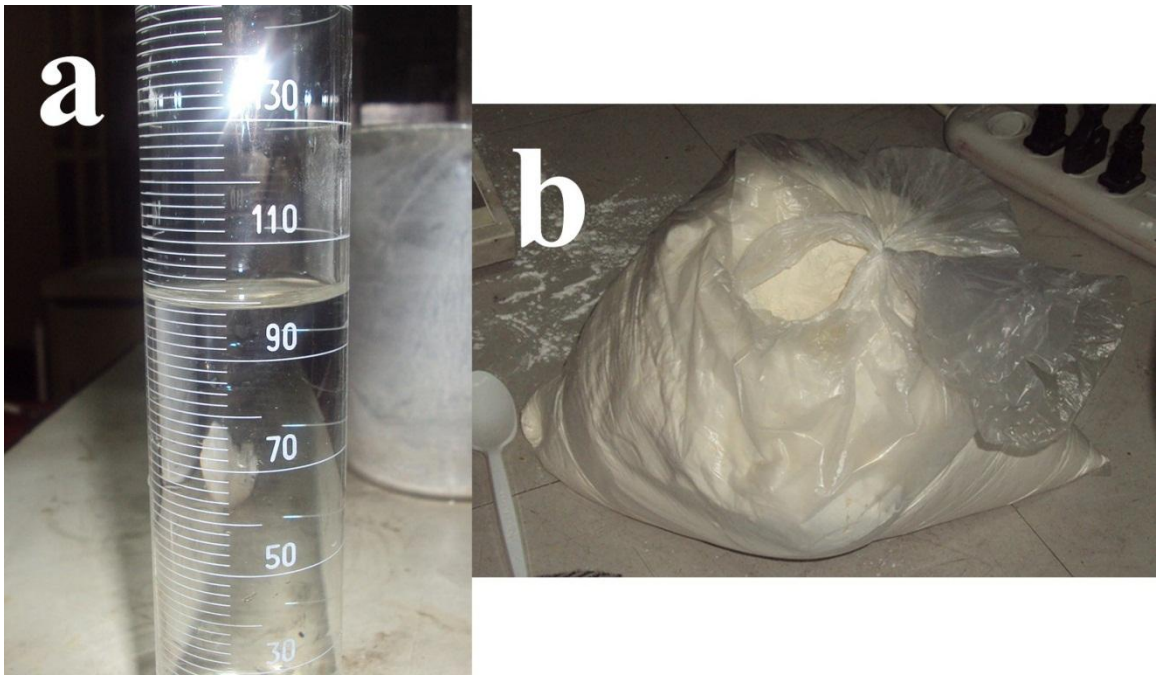


Figure 3.14. Binder Paste Ingredients: (a) Water and (b) Starch

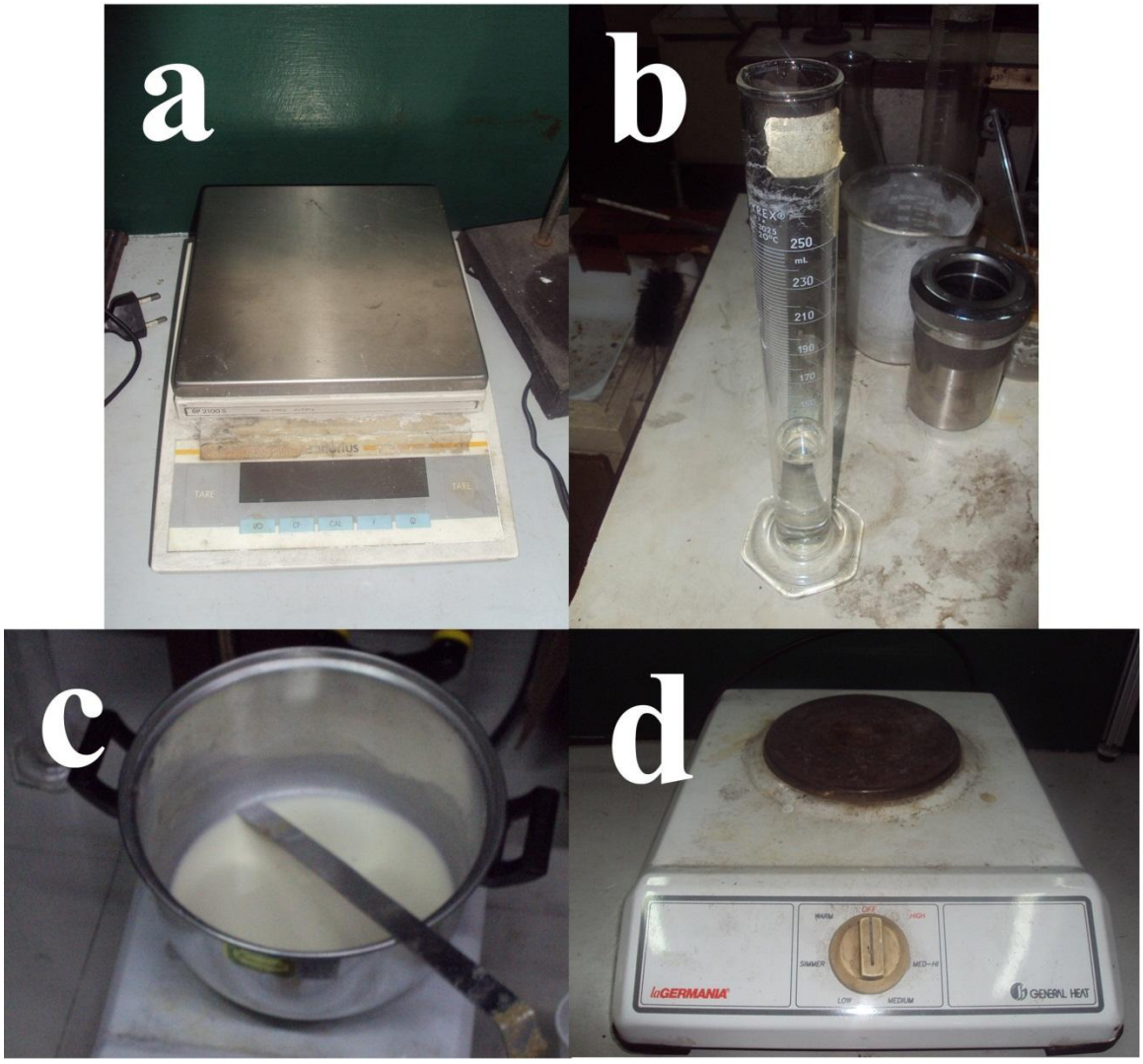


Figure 3.15. Apparatuses needed for Binder Cooking: (a) Analytical Balance, (b) Graduated Cylinder, (c) Cooking Pot, and (d) Electric Stove

As illustrated on the above image, 100 mL of water and 35 grams of cassava starch are the ingredient needed to create the binding paste for the briquette. The indicated quantities for each ingredient are intended for single sample of briquette.

To begin,60 mL out of the 100 mL of water is to be mixed with 35 grams of cassava starch into a bowl or container untilthe starch fully dissolved in the water and has no lumps. The consistency of the starch-water mixture should neither be too viscous (thick)nor too watery (drippy). The remaining 40 mL of water is to be heated in a pot or a can until it boils. Once it already boils, the starch-water mixture from earlier is to be poured unto it while being stirred. The overall mixture inside the pot should be stirred at regular intervals until becomes ready for mixing to avoid burning the binder paste which settles at the bottom of the pot. The binder is said to be ready for mixing or cooked when the paste already appears to be nearly translucent and feels gelatinous.

At this point, the preparation of the feedstock could now be realized. To do so, the cooked binder should be pouredinto the 70 grams groundrice husk on a separate container. After that, the two should be pre-mixed together manually (either by using a spatula or bare hands) so as tomake the feedstock become nearly homogenous before the binder solidifies.Presented in the portrait below, Figure 3.16, is an example of a feedstock that is ready for loading into the mixing chamber.

Figure 3.16. Sample Feedstock Ready for Loading

Overall, the ratio of the ground rice husk biomass to cassava starch binder is about 0.5783or 36.65 % rice husk and 63.35 % binder by weight. This ratio that was used during the testing was initially adapted from the study of Baconguis (2006) which was 8% to 15% binder by weight and 85% to 92% biomass by weight. Later on, the ratio was modified accordingly so as to fit for the purposes and bounds of this study.

3.5.2 Briquetting Operation Proper

Following the preparation of the feedstock, the operation proper of the briquetting press will then advance.First, the feedstock is to be loaded into the mixing chamber.In contrast with the initial mixing of the feedstock, the purpose of the mixing chamber in the study is for thorough and further mixing of the feedstock as well as to prevent it from solidifying prior to its compression.

Once the loading of the feedstock has been done, the machine will now be turned on so that the briquetting operation mayofficially begin. From the mixing chamber, the feedstock will be conveyed to the mold through the guide tube with the aid of gravity.While the feedstock accumulates and settles inside the mold, it is instantaneously being heated by the heating system of the machine at a temperature that was set by the user. As soon as the mold is already full and ready for compaction, it will move directly below the hydraulic press which marks the start of the compression proper of the operation.

An initial test run is to be conducted before having the machine totally engage into full operation which involves varying of both pressure and temperature.This test run will involve testing of whether the feedstock really became a briquette after going through the machineoperating at maximumavailable pressure and temperature. If the feedstock does not form into briquettes, then amendmentsare to be made such as an increase in the amount of binding agent and vary the preheatingtime until briquettes are formed.

The moment it has been confirmed that machine could really create briquette, test run with varying pressure and temperature could already be carried out.At runtime of the press, the installed control panelmay be used to monitorand regulate some of the briquetting parameters such as pressure and temperature. If an error occurred, the machine should be stopped; if no error occurred, then the operation continues. If a disturbance occurred, the built-in machinecontrols may be used;however, if the disturbance is uncontrollable,the machine has to be stopped.Nonetheless, if no disturbance occurred, then the operation continues. Figure 3.18 summarizes the briquette operation and testing phase.

In addition to Figure 3.18, Figure 3.17 shows a closer view of the densification operation that will be done using the machine. The densification operation to be done will follow a planned scheme to see if the automated briquetting machine is indeed flexible.

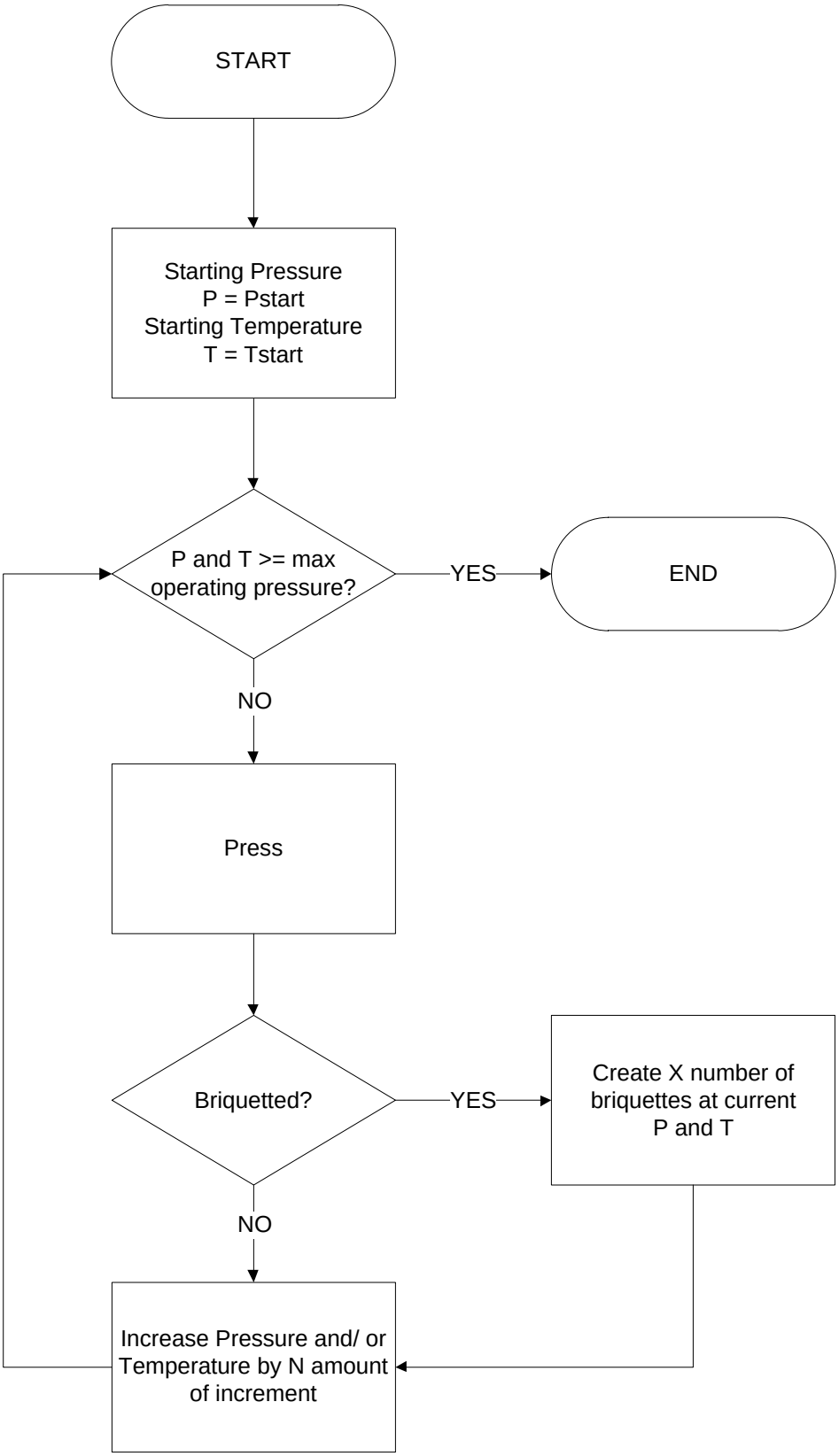


Figure 3.17. Densification Process

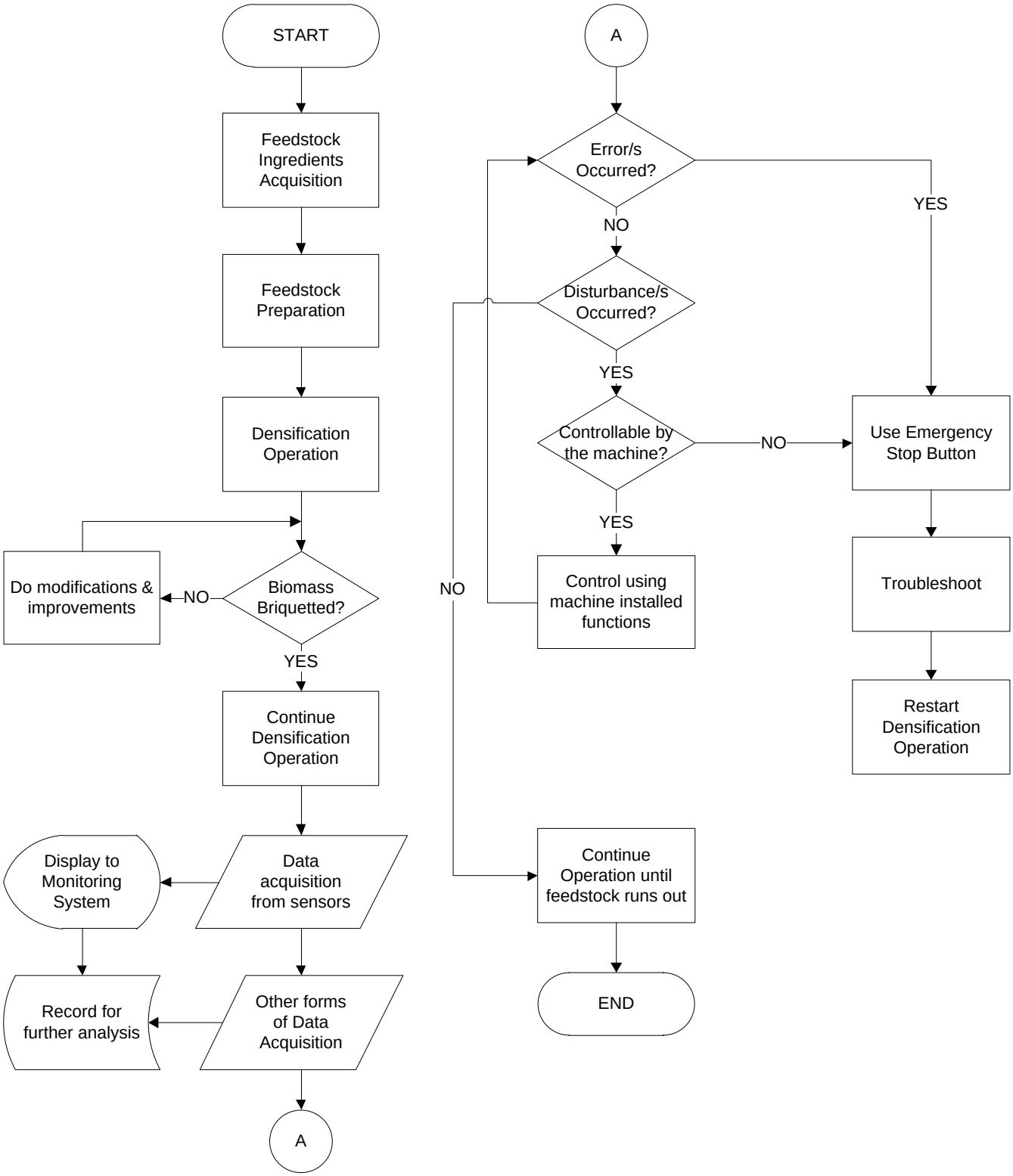


Figure 3.18. Summary of Briquette Press Operation and Testing

Chapter 4

RESULTS, ANALYSIS, AND CONCLUSION

This chapter presents the data gathered through simulations and experimentations done by the group. The simulations were done on the design phase of the study, before the actual fabrication and procurement of materials. The experiments are presented mostly in table form with their corresponding graphs. Also, the analyses of the data followed by the conclusion, are discussed on the latter part of this chapter.

4.1 Results

The results of the experiments conducted by the group, as explained in the previous chapter, are summarized in this section. On Table 4.1, a list of the parameters measured in the machine together with their corresponding monitoring unit used can be seen.

Table 4.1. **Parameters Monitored / Controlled**

Parameter	**Monitoring Unit**
Biomass level on the Mixing Chamber	Proximity sensor
Temperature	Temperature controller
Positioning of the mold	3 proximity sensors
Pressure	2 Pressure gauges and pressure switch

For continuous operation, a proximity sensor is attached to the mixing chamber. With the use of an indicator light, the user can know when the biomass level is low and needs refilling. In addition to that proximity sensor, 3 more inductive proximity sensors are used to position the mold. For the temperature aspect, a temperature controller with a thermocouple attached to the band heater is used to monitor the temperature at the mold. Lastly, 2 pressure gauges, one

attached before the solenoid valve and one attached before the vertical hydraulic cylinder, and a pressure switch are installed on the system to make sure that the pressure supplied to the biomass is correct.

4.1.1 Simulations

Several parts of the machine have undergone simulations such as stress analysis, factor of safety, etc. The results of the simulations done by the group are shown below while detailed reports can be seen on Appendices C, D & E.

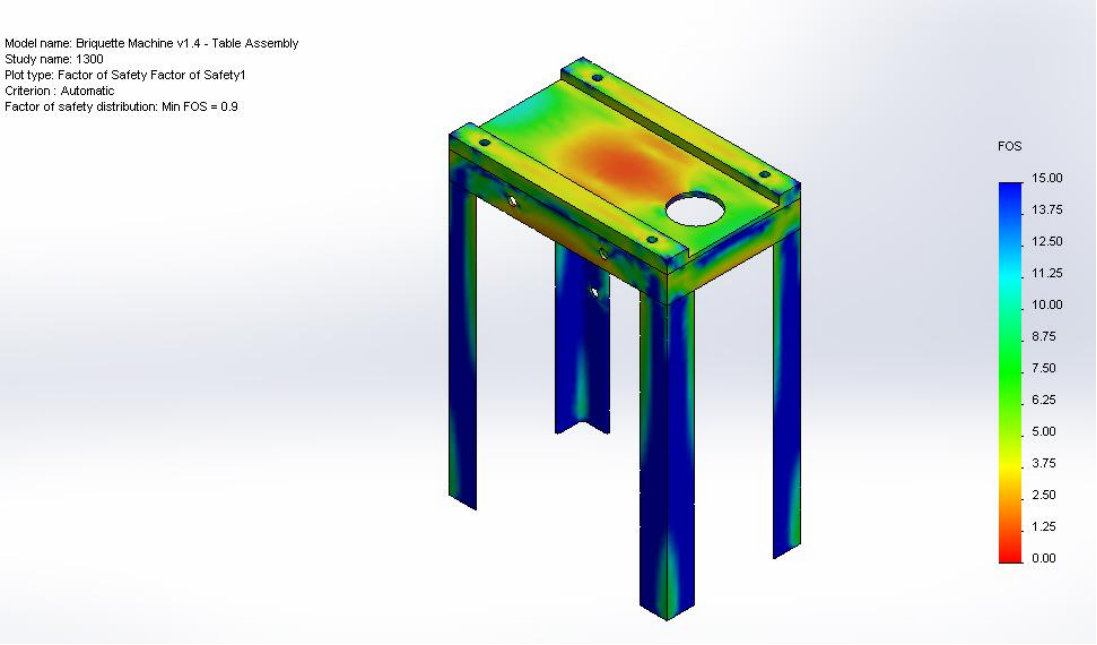


Figure 4.1.Factor of Safety Analysis on the Table Assembly

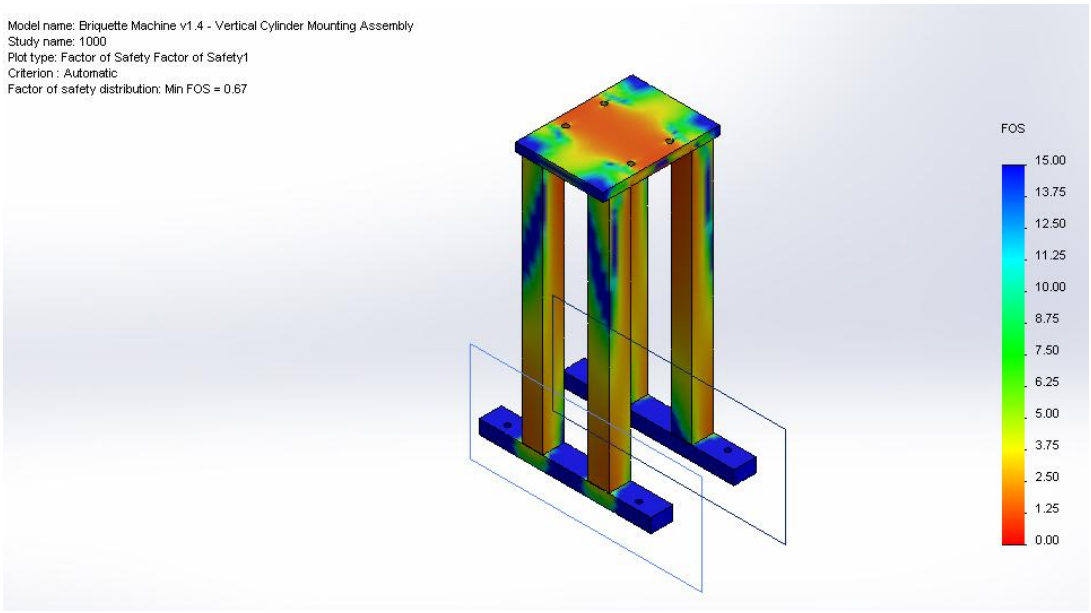


Figure 4.2. Factor of Safety Analysis on the Mounting of Hydraulic Press Assembly

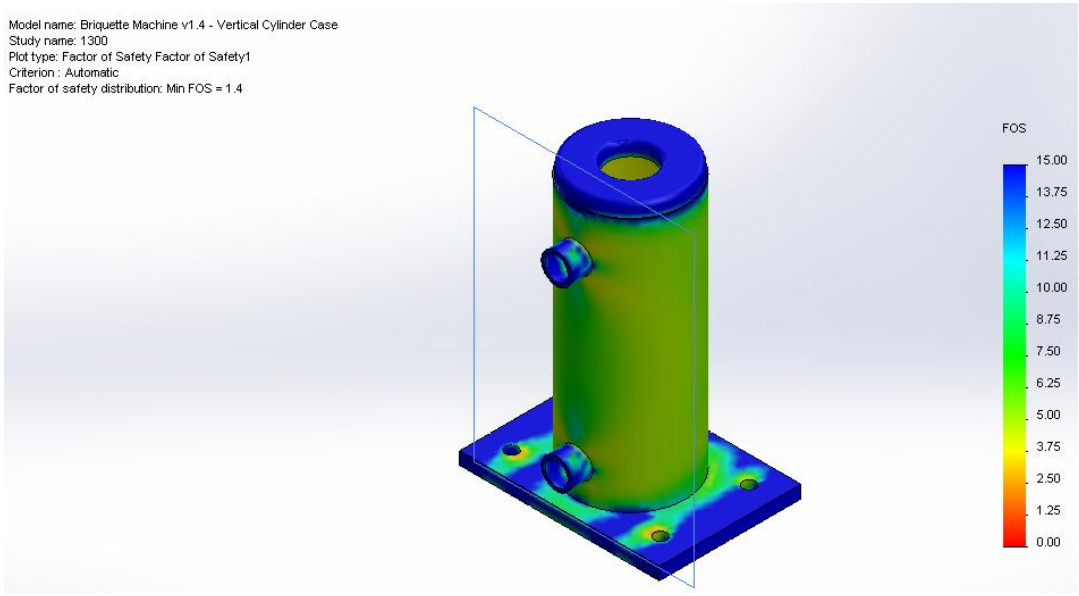


Figure 4.3. Factor of Safety Analysis on the Hydraulic Press Casing

These simulations were done using Solidworks 2012. The designs of these parts of the machine are based on readily available materials and existing parts. The results of the

simulations done are on the figures above but detailed reports can be seen on Appendices C, D & E.

4.1.2 Machine Operation

The data gathered during the machine operation proper is divided into three parts: heating system, pressure system, and the briquette formation. These are the major aspects of the machine that reflects the machine performance. Table 4.2 shows the operating parameters and the time needed for each.

Table 4.2. Operating Parameters Observed during Machine Operations

Operating Parameter	Working parameter
Stabilization of the Offshoot (Heating System)	3 – 4 minutes
Preheating Length	20 minutes
Pressing Time	1 minute

From the experimentations, it was observed that upon turning on of the heater, it takes around 3 to 4 minutes before the temperature stabilizes. Also, after a number of trials, it was determined that the minimum preheating and pressing time are 20 minutes and 1 minute, respectively.

4.1.2.1 Heating System

For the heating system of the machine, the temperature set by the user on the temperature controller was counterchecked by a thermocouple attached to the band heater. The readings on both the controller and the thermocouple are recorded on Table 4.3. Also, as the temperature was

varied, the time needed to achieve such changes was recorded. The data gathered on each trial are summarized on Table 4.4.

Table 4.3. Temperature Readings (in °C)

Temperature Controller	Thermocouple				%Difference
	Trial 1	Trial 2	Trial 3	Average	
0	0	0	0	0.00	0.00
30	35	33	33	33.67	10.89
40	46	44	41	43.67	8.40
50	54	53	51	52.67	5.06
60	64	61	65	63.33	5.26
70	72	71	73	72.00	2.78
80	81	82	80	81.00	1.23
90	90	91	90	90.33	0.37
100	98	100	99	99.00	1.01
110	110	111	110	110.33	0.30
120	119	123	121	121.00	0.83
130	129	132	131	130.67	0.51
140	138	142	140	140.00	0.00
150	149	148	152	149.67	0.22
160	157	161	160	159.33	0.42
170	166	169	171	168.67	0.79
180	174	177	181	177.33	1.50
190	186	191	193	190.00	0.00
200	194	198	204	198.67	0.67
210	208	210	212	210.00	0.00
220	214	219	225	219.33	0.30
230	227	234	228	229.67	0.15
240	239	240	242	240.33	0.14
250	249	252	251	250.67	0.27
260	258	264	258	260.00	0.00
270	265	270	272	269.00	0.37
280	273	281	277	277.00	1.08
290	281	288	286	285.00	1.75
300	293	295	298	295.33	1.58

For each trial, the temperature on the controller was set from 30 °C to 300 °C, with 10 °C increment. Once the temperature on the controller stabilizes, the temperature on the thermocouple is recorded, then the temperature is increased until it reaches the maximum temperature capacity of the heating system. This was repeated three times then the average temperature form these trials were computed. The average was compared to the temperature on the controller to achieve the percentage difference between these two readings.

Table 4.4. Temperature Readings with Time

Temperature Controller (°C)	Time (in seconds)		
	Trial 1	Trial 2	Trial 3
0	0.00	0.00	0.00
30	0.24	0.25	0.24
40	0.26	0.27	0.27
50	5.44	5.56	4.49
60	9.20	9.39	8.57
70	11.52	Skipped to	10.45
80	13.29		13.37
90	16.02		15.59
100	18.15		17.55
110	20.55		20.02
120	22.24		22.56
130	24.36		25.03
140	26.03	11.44	27.44
150	28.41	13.29	28.22
160	29.58	Skipped to	30.35
170	32.43		32.58
180	34.18		34.39
190	35.47	15.11	35.86
200	37.15	16.58	37.41
210	38.7	17.35	39.12
220	40.07	19.23	40.54
230	41.35	20.51	41.87
240	43.14	22.19	43.26
250	44.15	23.44	44.41
260	45.09	24.53	45.4

270	45.97	25.42	46.35
280	46.66	26.15	47.11
290	47.31	27.01	47.79
300	48.11	28.05	48.5

On another testing, the temperature was again taken but now, the time needed to reach the desired pressure was monitored. On Table 4.4, the data from the three trials can be seen. On Trial 1, the temperature was increased by 10 °C from 30 °C until it reaches 300 °C. As a pattern was observed by the group on the first trial, they increased the temperature by 80 °C at one point and 40 °C on another part, to see if it takes the same time as when it is increased by 10°C. On the third trial, the same increment of 10 °C was used.

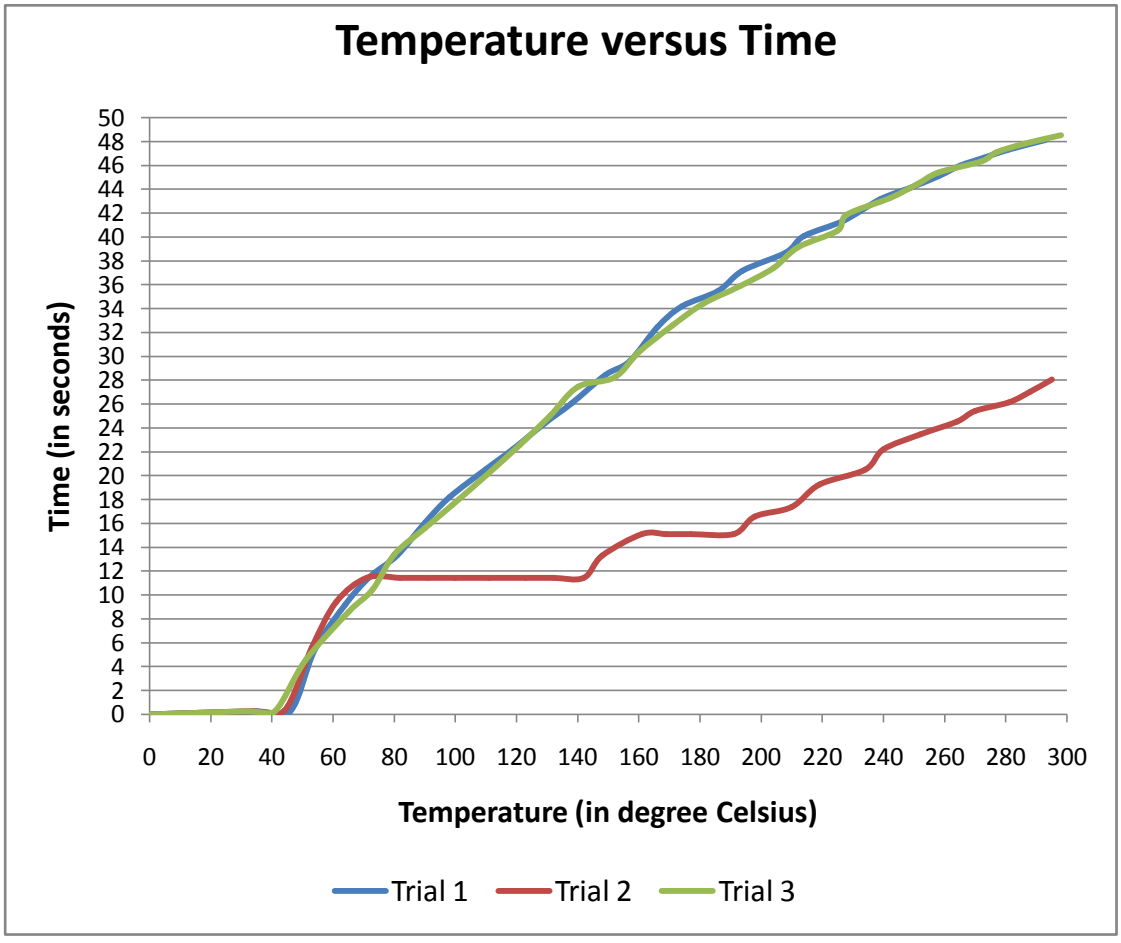


Figure 4.4. Temperature versus time graph

The relationship of the values on Table 4.4 is shown on this graph. The temperature set on the controller serves as the x-axis while the time needed to reach a certain temperature is on the y-axis. The three trials are represented by the three lines. The blue and green lines representing Trials 1 and 3 are almost coinciding, showing that the readings gathered on these trials do not differ much. However, since on the third trial, there was a huge increase on the temperature setting (increased by 80 °C, from 60 °C to 140 °C), it can be seen that the time used for that particular trial is shorter. Nevertheless, it can be observed that the three lines have the same slope, except for those parts where there was sudden increase in temperature.

4.1.2.2 Pressure System

For the next parameter, the pressure, the group has two pressure gauges attached to the system. The pressure set on the pressure switch is counterchecked by these two pressure gauges. The readings are summarized on Table 4.5.

Table 4.5. Pressure Readings (in kg_f / cm^2)

Trial 1

Pressure Switch Position	Pressures				% Difference
	PS Pressure (Convention)	PG 1	PG 2	Average Pressure	
W2 80°	55	57	58	57.5	4.35
N2	55	57	60	58.5	5.98
E2	60	63	64	63.5	5.51
S2	65	65	66	65.5	0.76
W3	70	68	68	68	2.94
N3	75	70	72	71	5.63
E3	80	73	73	73	9.59
S3	85	70	75	72.5	17.24
W4	90	82	88	85	5.88
N4	95	95	94	94.5	0.53

Trial 2

Pressure Switch Position	Pressures				% Difference
	PS Pressure	PG 1	PG 2	Average Pressure	
W2 80°	55	57	57	57	3.51
N2	58	60	58	59	1.69
E2	60	63	62	62.5	4.00
S2	65	65	63	64	1.56
W3	70	66	68	67	4.48
N3	75	70	72	71	5.63
E3	80	74	75	74.5	7.38
S3	85	72	75	73.5	15.65
W4	90	82	90	86	4.65
N4	95	94	95	94.5	0.53

Trial 3

Pressure Switch Position	Pressures				% Difference
	PS Pressure	PG 1	PG 2	Average Pressure	
W2 80°	55	56	57	56.5	2.65
N2	58	58	62	60	3.33
E2	60	63	64	63.5	5.51
S2	65	65	66	65.5	0.76
W3	70	67	68	67.5	3.70
N3	75	70	73	71.5	4.90
E3	80	73	75	74	8.11
S3	85	70	77	73.5	15.65
W4	90	80	90	85	5.88
N4	95	93	94	93.5	1.60

On the three trials, the pressure setting on the pressure switch was increased by 5 kg_f / cm^2. The tests done were based on the convention set by the group as explained on the Methodology part of this study. After setting the pressure on the switch, the two pressure gauges were observed while the machine was operating. The readings from the two pressure gauges

were also recorded together with their computed average. Afterwards, the percentage difference between the set pressure and the actual pressure was calculated.

For the first trial, most of the readings are within the tolerance limit of 10 % except that on S3. The same observations can be done on both Trials 2 and 3. The analysis of this data can be seen on the Analysis part of this Chapter.

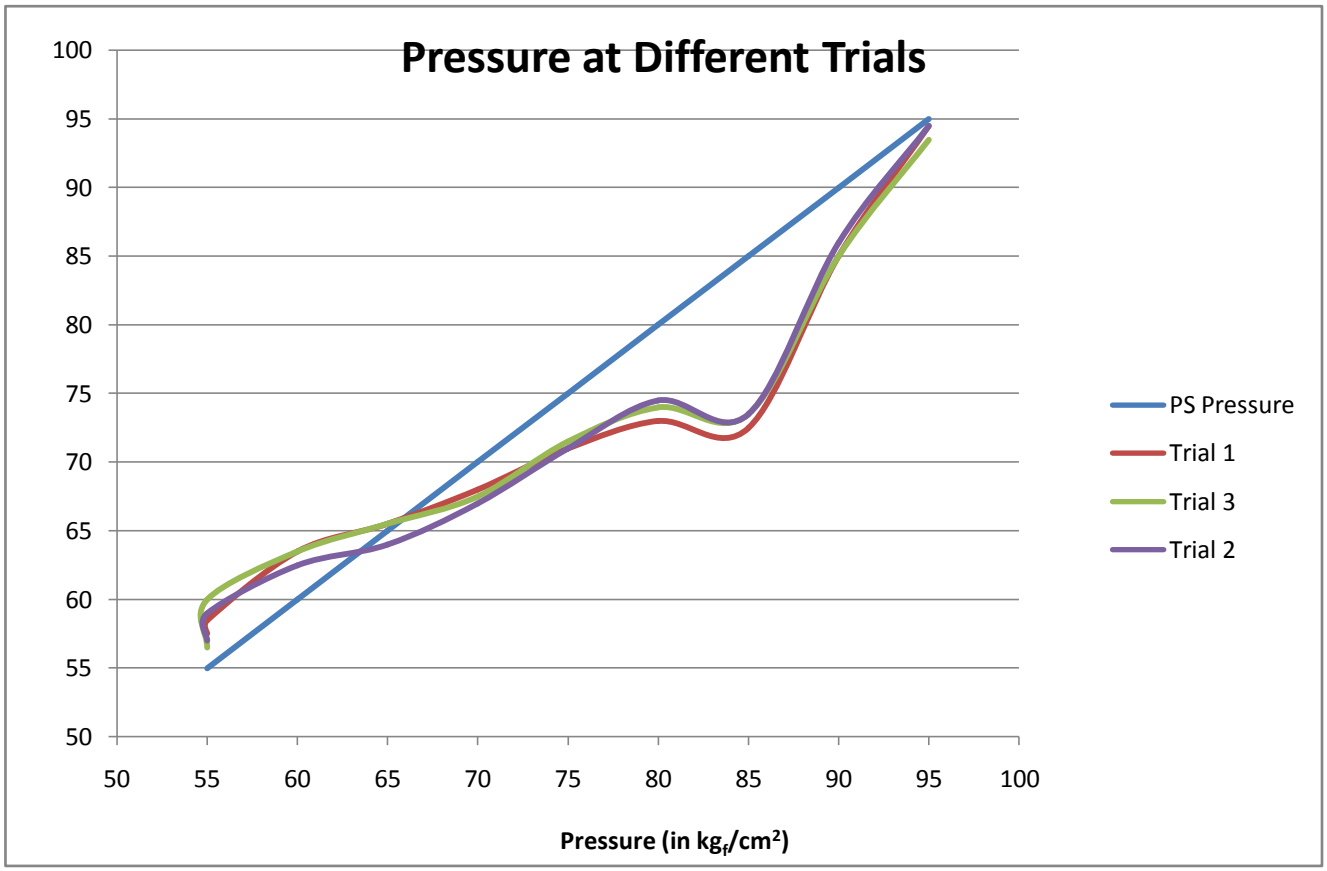


Figure 4.5. Graph of the Pressures at Different Trials

On the graph, the set pressure on the pressure switch is represented by the linear blue line while the three other lines represent the three trials. It can be seen that the green, red, and violet

lines behave almost identically, showing that the data gathered on the three trials are almost the same. However, these three lines do not behave the same as the blue one, showing that there are differences on the pressure read by the gauges and that set on the pressure switch. These differences are explained on the Analysis part of this chapter.

4.1.2.3 Briquette Formation

Varying the parameters, the group has identified the temperature and the pressure where the briquette actually forms is listed on Table 4.6. Pictures of some of the briquettes are shown on Figure 4.6.

Table 4.6. Briquetting Parameters Overview

Temperature (deg C)	Pressure (kgf/cm2)	Briquette Formed	
		Yes	No
0	55		x
10			x
20			x
30	60		x
40			x
50			x
60			x
70	65		x
80			x
90			x
100			x
110	70		x
120			x
130			x
140			x
150	75		x
160			x
170			x
180			x
190	80		x

200		x	
210		x	
220		x	
230	85	x	
240		x	
250		x	
260		x	
270	90	x	
280		x	
290		x	
300		x	

On this table, the corresponding pressure and temperature where the briquette forms a cylindrical hollow shape are recorded. The group pressed briquettes using varied operating temperature and pressure, as listed on Table 4.6. It was observed that at 200 °C and at 80 kg_f / cm^2, the briquettes removed from the mold hold their form until it can be transferred to a container for further air or sun drying.

Figure 4.6. Briquette Samples

The picture on the upper left was pressed with an operating temperature and pressure of 60 °C and 60 kg_f / cm^2, the one on the lower left at 100 °C and 65 kg_f / cm^2, while on the upper right at 150 °C and 75 kg_f / cm^2 and lastly, the one on the lower right at 200 °C and at maximum pressure of 95 kg_f / cm^2. It can be seen that on the first picture, the briquette instantly crumbles

down once removed from the mold while the second and third formed into cylinders but do not stay firm for long. With the proper parameters, it can be seen on the last picture that the briquette was formed properly and after some drying time, it became hard enough to not break even when dropped on the floor. These physical characteristics of the briquette show how pressure and temperature affect the compaction, texture, and firmness of the briquettes.

4.1.3 Economic Evaluation

For the economic evaluation of the machine, the number of units sold and the number of years of operation before return of investment is achieved, are computed in the tables below. On the computation, the cost of the machine and the daily operating expenses were taken into account and are also listed below.

4.1.3.1 Existing Manually Operated Briquette Machine

The computations found on this section are based on for the manual briquetting machine used by the Industrial Technology Development Institute of the Philippines' Department of Energy (ITDI – DOST). These machines are used by some of the citizens in rural areas of the country. These data were gathered from the paper of Bawagan (n.d.).

The briquettes made by ITDI – DOST were sold for Php 50.00 per kilogram. Based on Bawagan (n.d.), the machine capacity is 2,500 kilograms of briquette in a month operation. The machine operates 25 days a month at 8 hours per day. In their computation, the payback period is 3.9 years or after selling 138,420 briquettes. The following expenses are summarized on the following tables.

Table 4.7. Cost of the Machine

Equipment	Price (in Php)
Drum type carbonizer	40,000.00
Gas engine operated hamermill crusher (5 hp)	50,000.00
Manual type mixer	7,500.00
Manual type briquettor	20,000.00
LPG Stove Burner	1,500.00
Production Accessories	1,000.00
Total	120,000.00

The individual equipment needed in manual briquetting with their corresponding cost are seen on Table 4.7. Since manual briquetting utilizes separate carbonizer, crusher, mixer and press (briquettor), they all contribute to the expense of the machine.

Table 4.8. Daily Operation Expenses (in Php)

	Cost/kg	Total Cost
Materials	8.16	816.00
Direct Labor Cost	5	500.00
Factory Overhead		
Fuel	0.19	19.00
Utilities	0.36	36.00
Packaging	0.78	78.00
Repairs & Maintenance*	0.04	4.00
Factory supplies	0.05	5.00
Total	14.58	1458.00

*Repairs and maintenance is assumed 1% of initial cost of equipment

In preparing the feedstock and in operating the machines needed in forming briquettes, the electrical and material costs should also be taken note of. Materials such as the binder and the biomass itself, labor costs for the machine operators, and other related fixed costs, were identified for effective computation. And as seen on Table 4.8, the daily operating expense of a manual briquette machine is Php 1,458.00.

4.1.3.2 Automated Briquette Machine

The expenses in manufacturing the experimental automated briquette machine were tallied and are summarized in this section. From that list, the group canvassed the additional expenses if the machine is to be used for mass production. The operating expenses such as the electricity and the binder were also considered in computing for the payback period. The expenses for both the experimental and the mass production machine are listed below.

4.1.3.2.1 Assumptions

In the computations, the following assumptions were used:

Table 4.9. Assumptions

1 briquette = approximately 70 grams	8 hours / day operation (1 hour for binder preparation)
1 kg = 15 briquettes = 1 batch of pressing	35 kg / day production
1 batch = 12 minutes, thus 5 batches = 1 hour	25 days / month operation

The briquette weight was measured using a digital scale and found out to be approximately 70 grams. The planned automated machine for mass production have 15 molds, thus in one press / batch, 15 briquettes will be formed. Based on the experimental machine, it

takes 12 minutes for a batch to be formed, resulting to 5 batches formed in one hour. From these values, the machine has an estimated 35 kg / day production.

Table 4.10. Cost of Machine (Experimental and for Mass Production)

Part	Experimental	Mass Production
	Price	**Price**
Machine Fabrication	68,000.00	150,000.00
Heating System	6,224.00	20,000.00
Pressure Switch	6,500.00	6,500.00
Pressure Gauge	500.00	500.00
Electrical appurtances (wires, switches, etc.)	3,000.00	3,000.00
Solenoid Valve	-	8,000.00
Proximity Sensors	-	2,400.00
PLC	-	10,000.00
Total	**84,224.00**	**200,400.00**

All the expenses on the production of the experimental machine are tallied on the second column. For the mass production machine, the expenses for the modification of the machine and the purchase of the components that were only borrowed by the group from the University are listed on the third column. It can be seen that the total cost of the experimental machine and the mass production machine are Php 85,224.00 and Php 200,400.00, respectively.

4.1.3.2.2 Daily Operation Expenses

Table 4.11 Electrical Consumption

Part	Power Consumption (kW)	kWh/day
PLC	0.08	0.64
Power Supply (3)	0.44	10.56
Heater	0.5	4.00
Motor 1 (3 hp)	2.2371	17.90

Motor 2 (0.5 hp)	0.37285	2.98
Electrical Stove	1	1.00
Blender	0.35	0.35
Total	4.98	37.43
Price per kwh	Php 10.50	
Electrical Consumption expenses / day	Php 393.01	

All the equipment that needs electricity are listed on Table 4.11 together with their corresponding power rating. Multiplying with the amount of time they are used in a daily basis, the electrical consumption of each equipment was identified. The price per kilowatt was based on the average price in Metro Manila were the experimental machine is located.

Table 4.12. Biomass Preparation

Biomass-related expenses	**Consumption (kg/day)**	**Unit Price (Php / kg)**	**Price (in Php)**
Biomass (Php 30/ 20 kg sack)	40	1.5	60.00
Starch (Php 45.00 / kg)	21	45	945.00
Water (Php 0.028 / liter)	60	0.028	1.68
Total	121	46.53	1,006.68

For the experimentations done in this study, a sack of rice hull and starch were purchased. Based on the amount of binder used in every experiment and the price of each ingredient, the cost of the feedstock per day was identified.

Table 4.13. Summary of Operating Expenses per day

Consumption	Price (in Php)
Electricity	393.01
Biomass-related	1,006.68
Total	1,399.69

From Tables 4.11 and 4.12, the summary of the total expenses in the daily production of briquettes are found. These values are based on actual experiments conducted by the group.

4.1.3.2.3 Return of Investment Computation (Daily Operation Basis)

- Production = 35 kg / day
- Selling Price = Php 50.00 / kg (same with the existing manual briquette machine)

Capital (Equipment Expenses)	Php	170,400.00
Gross Income		1,750.00
Daily Operating Expenses		(1,399.69)
Net Income	Php	350.31

Thus,

In the case that a mass production machine is fabricated based on the existing experimental machine, the ROI of that machine is estimated to be achieved after **1.91 years** or after selling **300, 334.68 briquettes**.

4.2 Analysis of the Data

4.2.1 Simulations

The group simulated three of the most crucial parts of the machine that are subjected to stress. These parts are the table assembly, the mounting of vertical cylinder and the hydraulic press (vertical cylinder).The group focuses on the results of simulation on deformation and factor of safety since these two quantities will be the basis for the design.

On Figures 4.1, 4.2 and 4.3, the results of the simulation on factor of safety on the table assembly, on the mounting of hydraulic cylinder press and on the hydraulic cylinder press, respectively, are seen. The figures are composed of different colors ranging from red to blue that represents the factor of safety range from 0 to 15. These colors represent the intensity of the factor of safety distribution on the simulated part.

In Figure 4.1, it shows that the middle part of the table has an orange color which means that its factor of safety is in between 0.75 to 2.00. The "legs" are mostly blue in color, implying that its factor of safety on that portion of the assembly is around 15.00. In analyzing the figure, the "legs" of the assembly are safe but the middle of the table can be subjected to failure. But since the applied load (1300 psi) is 30% higher than the actual load, the factor of safety is acceptable.

In Figure 4.2, the factor of safety distribution on the mounting of the hydraulic press assembly is shown. The simulation results show that the "legs" and the upper base of this part are subjected to high deformation and stress because of its factor of safety ranging from 1.75 to 3.00.

However, as mentioned earlier, the applied load is also 30% higher to the actual load, thus, this factor of safety is acceptable.

In Figure 4.3, this figure shows the simulation on the casing of the hydraulic press. Based on the simulation results, the component has a high factor of safety ranging from 5.00 to 8.50. these figures indicate that the component has a low chance of failing. The results of the simulations done by the group are shown below while detailed report can be seen on Appendices C, D & E.

4.2.2 Machine Operation

4.2.2.1 Heating System

Based on Table 4.3 it can be seen that the percentage differences between temperature set on the temperature controller and the reading from the pocket thermocouple, is within the tolerance range of ± 10%. After three trials, the average temperature was taken and compared with the designated temperature on the controller to compute for the percentage differences. As seen, only at one time was the fluctuation over 10 %, at the 30° C reading. This can be attributed to the surrounding temperature where the experiments were conducted. Since most of the experiments were done on the months of May and June 2012 when the weather once reached over 35° C, the band heater had a hard time keeping the temperature down to 30 ° C. Also, eighteen out of the twenty eight readings has almost negligible percentage difference, less than 1 %. It shows that the heating system provides effectively the amount of temperature it is tasked to provide.

For the time needed to reach a certain temperature, the group monitored it using a stopwatch at every increment. During the experimentations, at the beginning of operation, it was observed that there is an offshoot of around 10-12 % but stabilizes after around four minutes, as seen on Table 4.4. On the two trials, the time was taken at every 10 °C and it can be observed that it takes approximately two minutes. But when it reaches around 180 °C, the time requirement decreases to one and a half minutes until it reaches 250 °C, wherein only a minute is needed. In addition, the group also tried varying the increase in temperature. As seen on the Table 4.4, at Trial 2, from 60 °C to 130 °C and 150 °C to 190 °C, it also takes around two minutes - same as when the temperature is increased by just 10 °C. This signifies that regardless of how much the temperature is increased, it needs only a maximum of around two minutes. It indicates that the heater should be turned on at least four minutes before the operation (even during binder preparation), to reduce idle time. Moreover, it was examined that as the temperature increases, the offshoot decreases, thus resulting to shorter stabilization period.

As expressed on the Methodology part of this study, the production of briquette requires a preheating of approximately twenty minutes, before pressing. This is to compensate the carbonization process which minimizes moisture and increases the briquette's heating value, done in manual briquetting, as discussed by Bawagan (n.d.). The length of preheating was identified through several trials, ranging from no preheating at all to 30 minutes. Below 20 minutes of preheating produces moist briquettes that deforms quickly upon removal from the mold while more than 20 minutes makes the briquette too dry and more difficult to press.

It should also be taken note that the temperature readings on Table 4.3 are that emitted by the band heater and not what the biomass actually receives. It is because of the width of the mold that traps the heat, reducing the actual temperature that reaches the biomass. The experimentations done by the group verified that the temperature set and displayed in the temperature controller is really what the band heater emits.

4.2.2.2 Pressure System

Through the convention assigned by the group, it can be seen that the percentage differences between the average pressure readings from the two gauges and the set pressure of the pressure switch, meet the tolerance level of ± 10%. Also, based on the experimentations, it was learned that a minimum of 25 kg_f / cm^2 is needed to move the horizontal cylinder and 55 kg_f / cm^2, for the vertical cylinder. These operating pressures set the pressing pressure to a range of 55 to 95 25 kg_f / cm^2.

Another factor that affects the pressure readings was the method used to record them. The group recorded the pressure gauges using a digital camera and phone cameras. After the machine operation, the pressure readings were taken by the group members as the videos were watched. Even though the videos were repeatedly watched before taking note of the pressure, human error can still play a part on this aspect of the study.

Lastly, it can be seen that at S3, the pressure switch sets only at around 73 kg_f / cm^2, though it should be at 85 kg_f / cm^2, following the convention set by the group. However, at W4, the pressure abruptly increases to approximately 85 kg_f / cm^2, which is within the tolerance range

set by the group but breaking the 5 kg_f / cm^2 increment convention. This can be attributed to a malfunctioning dial or to a not-well-distributed pressure increment of the pressure switch, since at N4, the pressure on the pressure switch corresponds again to those on the pressure gauges.

4.2.2.3 Briquette Formation

On Table 4.6, the minimum and maximum pressure and temperature needed to form briquettes are identified. It shows that at least 200 °C and 80 kg_f / cm^2 is needed to form briquettes that will not crumble upon removal from the mold. From the experimentations of the group, it was found out that if the temperature or the pressure is less than 200 °C or 80 kg_f / cm^2, the briquette cannot withstand the force applied to remove it from the mold – it instantly crushes upon removal. On the other hand, if the temperature and the pressure are increased above the minimum, less air / sun drying needed; it do not make the briquette stick to the mold or more difficult to remove.

4.2.3 Economic Evaluation

Taking into account the machine expenses and the machine daily operation expenses such as rice hull and binder prices and electrical consumption, it was computed that the return of investment (ROI) will be achieved after approximately 2 years, more than a year shorter than that of the manual machine (Bawagan n.d.), with the same selling price of Php 50.00 / kilogram. This may be attributed to the relatively large initial expense needed for manual machines since it requires a separate individual equipments such as the carbonizer.

For the mass production automated machine, it can be seen that a capital of approximately Php 200,000.00 is needed, same as with the manual machine. Even though less

briquettes are produced in the automated machine, since it weighs more less briquettes are needed for the per kilo selling. However, since different types of biomass and binders have different weights, this can vary. Also, the prices may vary based on the time of machine production and project implementation.

4.2.4 Overall Machine Performance

The automated machine prototype that was made for this study is able to adjust pressure and temperature more accurately and through automated means. The temperature could be adjusted by pressing buttons on the control panel while the pressure could be adjusted through a knob attached to a switch. Also, the machine operation was done with the use of buttons and switches; thus, allowing the user to operate the machine even at a distance from it. When a problem arises, the operator would be not affected directly and an emergency stop button could be triggered to stop the operation.

For all the parameters set by the group, the values obtained during experimentations were within the 10% tolerance range. This implies that the machine is accurate and is effective in giving off the pressure and temperature desired for the operation. Moreover, due to the manual and automatic operating options of the machine, it gives the machine its versatility. In the manual setting, the operator could control the hydraulic system, i.e. movement of the cylindrical mold and briquetting operation, using a toggle switch made into a joystick. In the automatic setting, on the other hand, the machine could be left to operate in itself according to set program until the very last step of the operation.

4.3 Conclusion

From the experiments done and the data gathered, it can be justified that the group achieved the objectives of this study. A small-scale automated briquette machine was designed and fabricated that can produce briquettes automatically, without human interference, upon the loading of the feedstock. Along with that, the primary operating parameters, the temperature and the pressure, can be varied through the control system utilized in the machine. These parameters can be observed through the gauges and the display screen, allowing the user to easily monitor the changes in the machine. Also, the accuracy of the heating and the pressure system were validated repetitively during several trials. These were done with the use of two pressure gauges and a pocket thermocouple that simultaneously takes readings. After the experimentation, it was computed that the data gathered complies with the set tolerance level.

With the PLC serving as the heart of this control system, variations in the relationship of the inputs and outputs in this machine are done through changes in the program; not through repetitive wiring. Since it also has access to the primary parts of the machine, immediate shutdown can be done, in case uncertain circumstances arise.

Using the economic evaluation done on the machine, it can be observed where the bulk of the expenses were spent at, allowing further studies to minimize the cost. By doing that, the aim of using an automated briquette machine for mass production, is a step closer to realization. Lastly, this dissertation promotes further studies on the use of biomasses to supply part of the country's energy needs with high quality briquettes. This machine can help in understanding deeper the different characteristics of briquettes, optimizing their use. It hopes to enlighten the

path to more researches and to maximize the potential into this overlooked capability of our agro-wastes.

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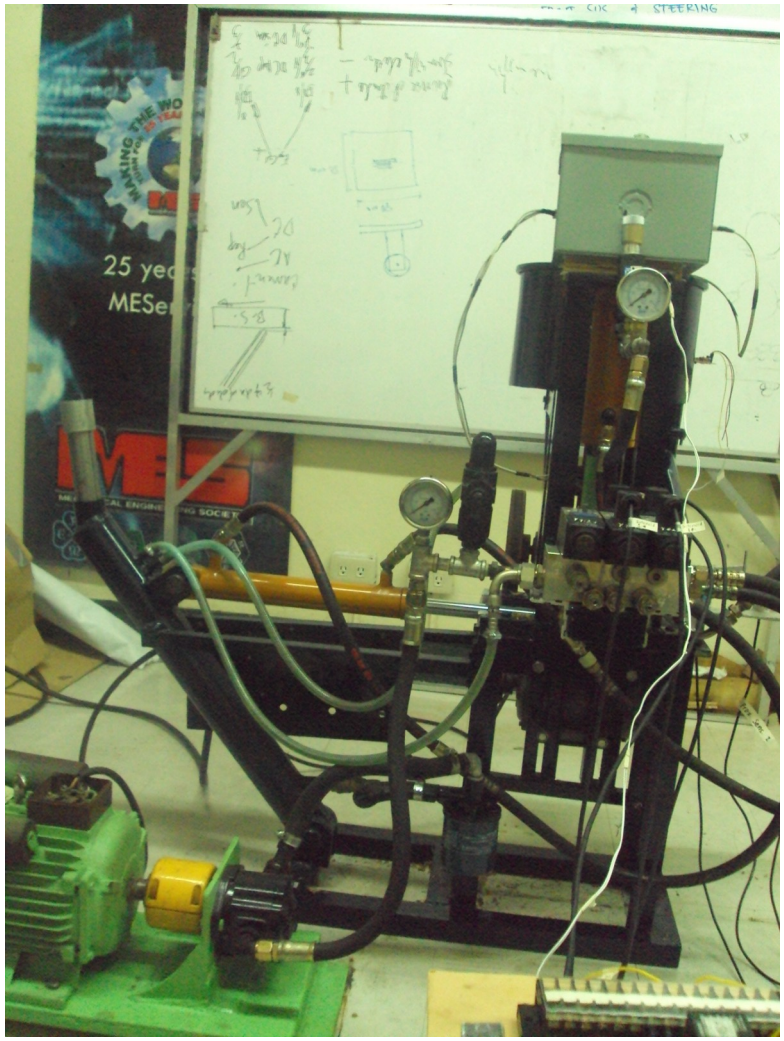
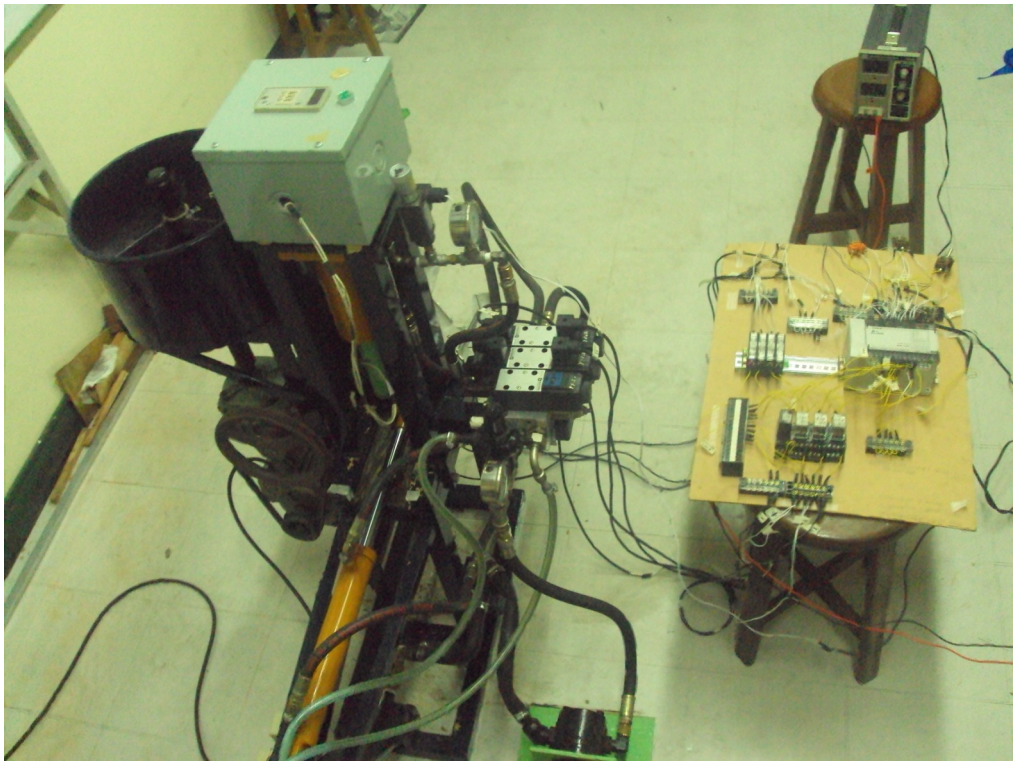
APPENDIX A

Actual Pictures of the Machine



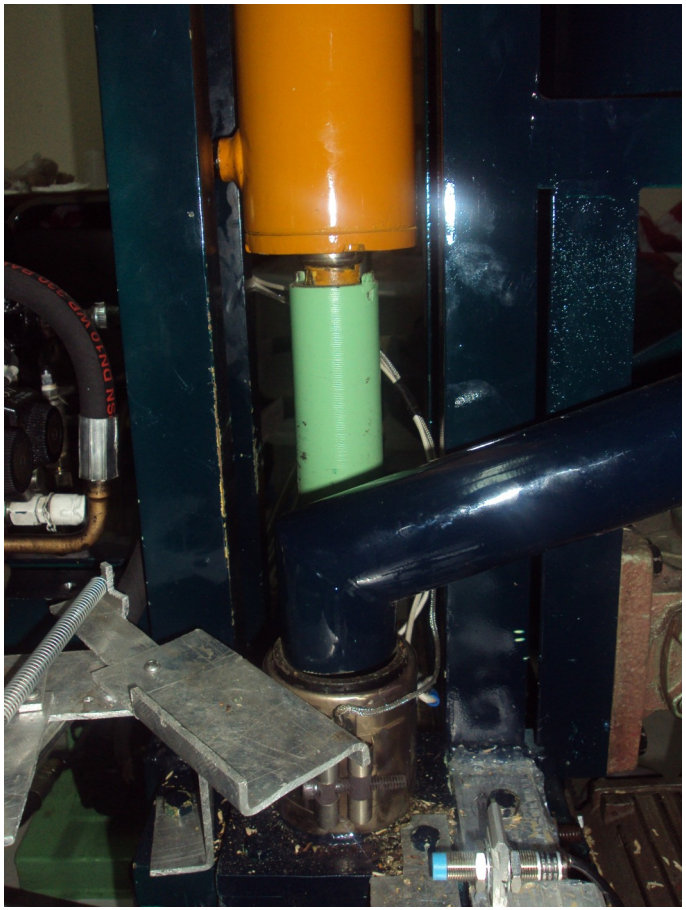


Mixing Chamber / Hopper

Motor and Pulleys

Mixing Chamber

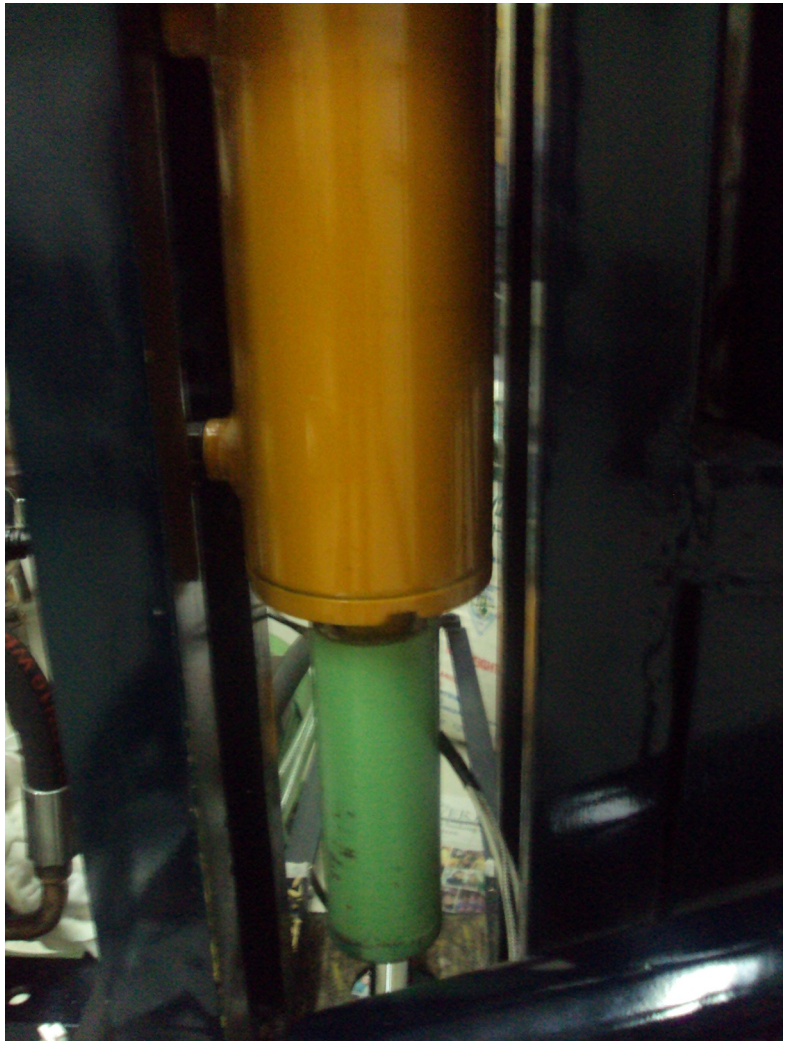
Heating System



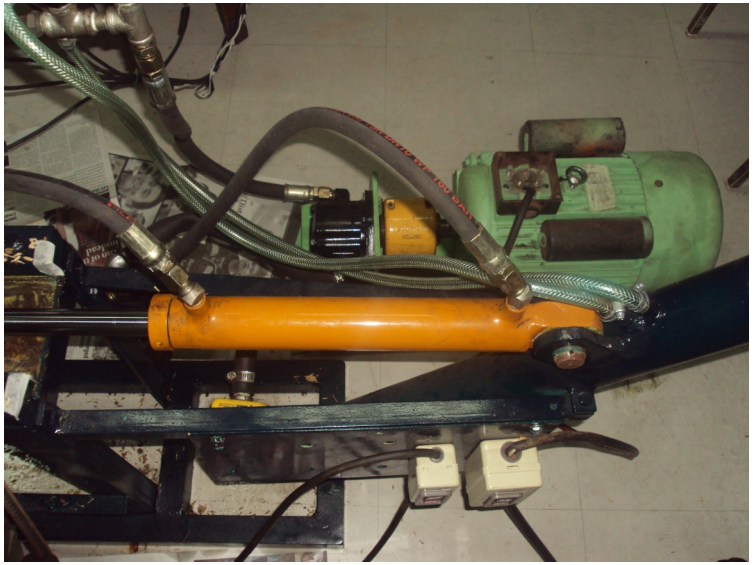
Band Heater

Temperature controller

Hydraulic System



Band Heater



Horizontal Hydraulic Cylinder

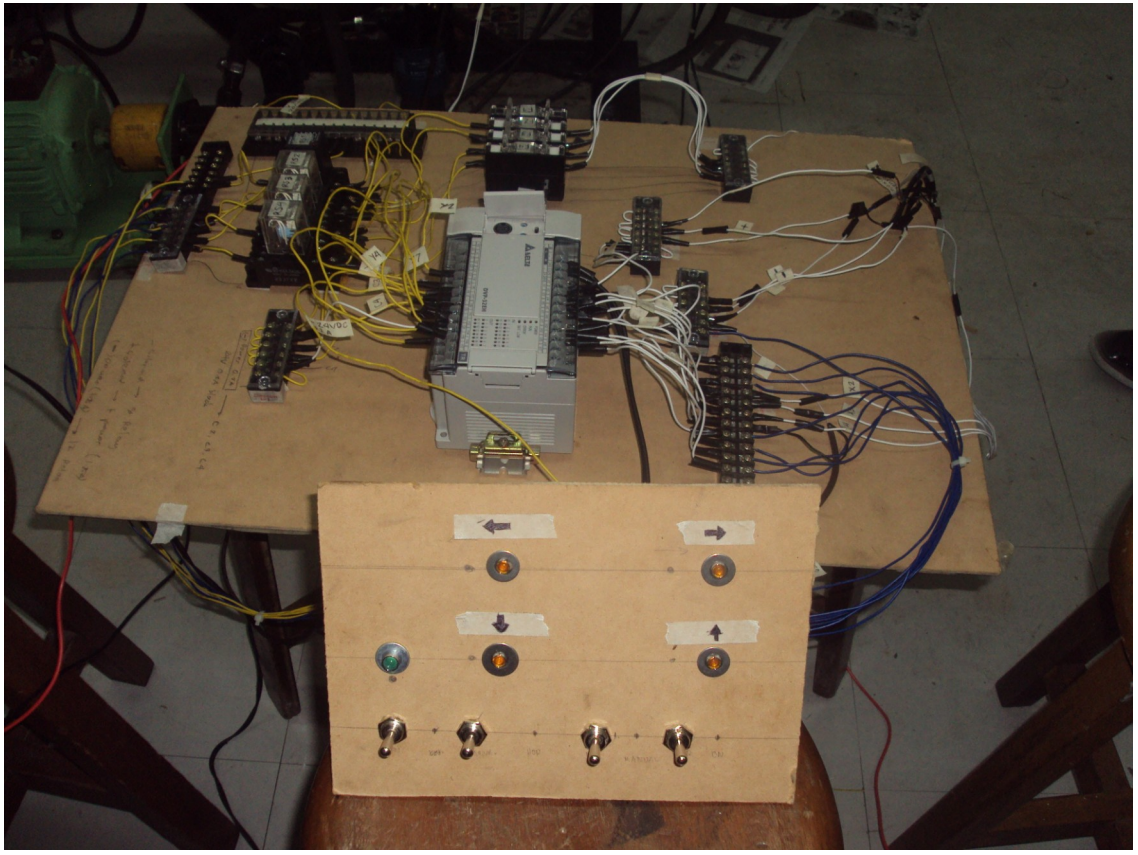
Pump and Motor

Hydraulic System

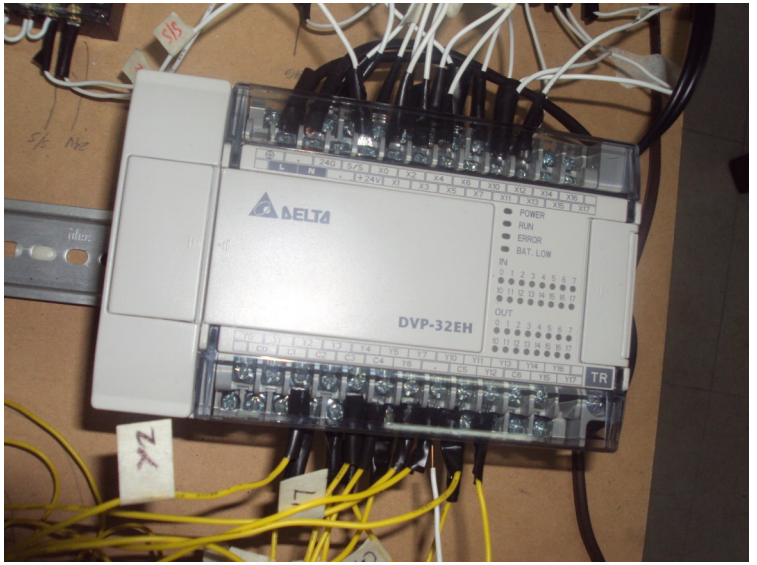
Pressure switch

Pressure gauge

Controls System



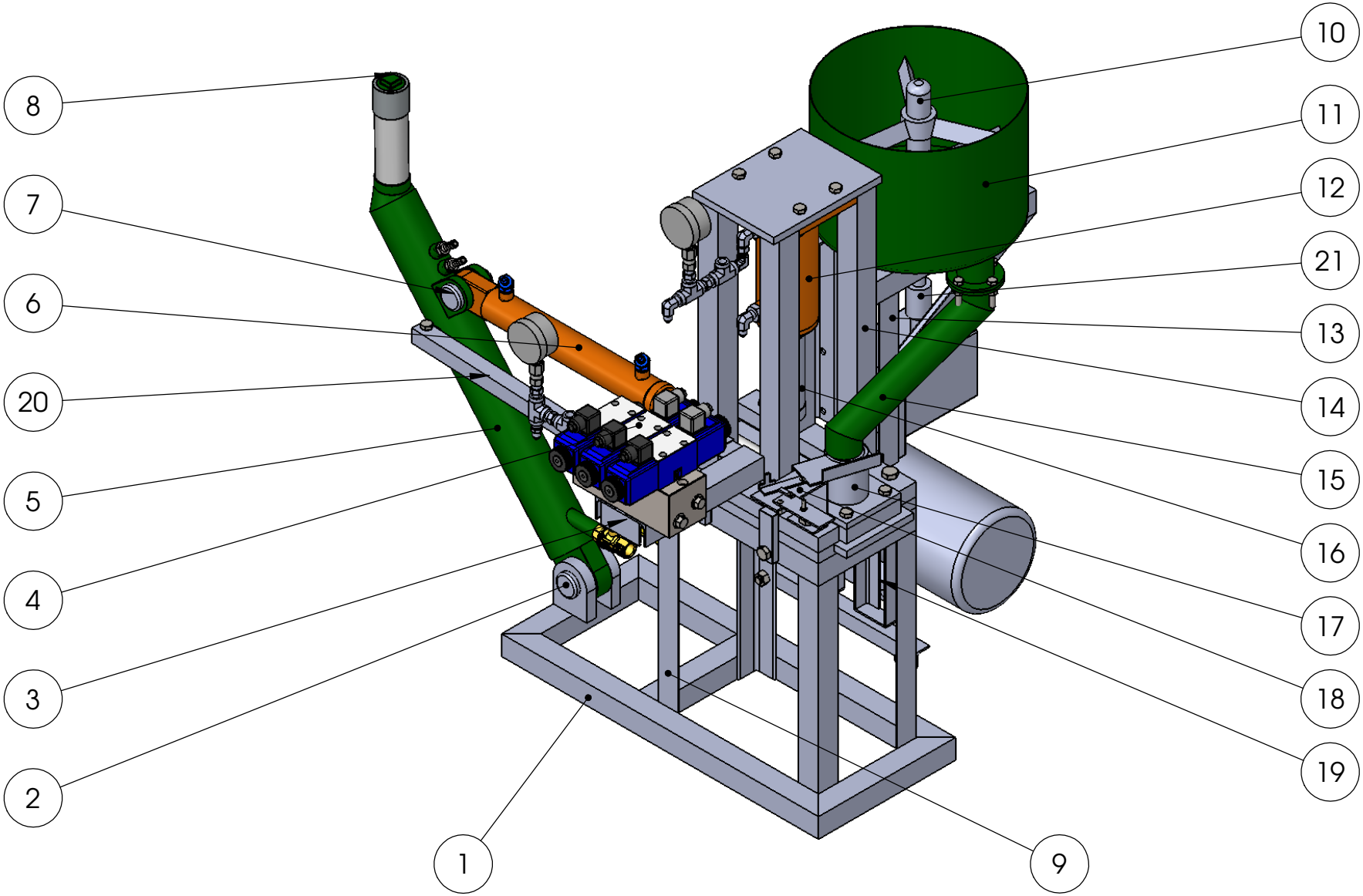
Controls connection and control panel



Programmable Logic Controller

Solenoid valves

APPENDIX B



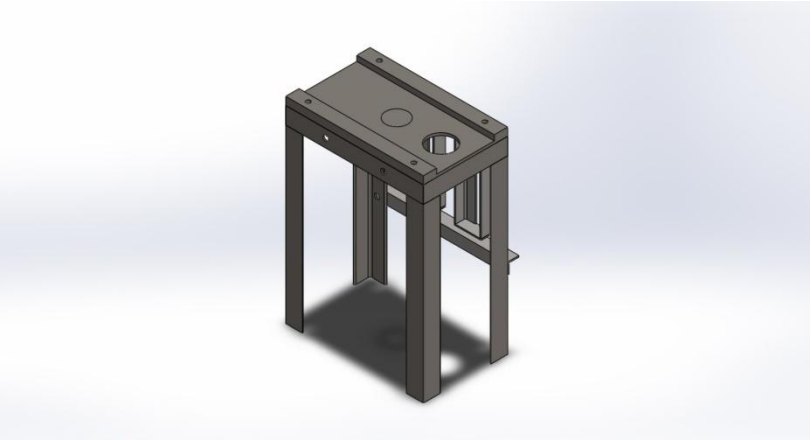
DRW NO 1	**Assembly Name:** Briquetting Machine Assembly		QTY 1
PART NO x	**Part Name:** n/a		SCALE 1:8
De La Salle University			MATRL n/a
THESIS	Designed by	T.Guanlao, R.Guting, A.Gatmaitan, C.Janairo	Date July 10, 2012
	Drawn by	T.Guanlao	Revised
	Approved by	Dr. Alvin Chua	Units mm

Item No.	Assembly / Part Name	Description	Quantity
1	Bottom Base Assembly	From Drawing no. 3-A to 7	1
2	Hydraulic Tank - Bottom Base Bolt	Drawing no. 8	1
3	Solenoid Mounting Assembly	From Drawing no. 9A - 12	1
4	Solenoid Assembly	Drawing no. 13	1
5	Hydraulic Tank	Drawing no. 14	1
6	Horizontal Hydraulic Cylinder Assembly	Drawing no. 15 and 16	1
7	Hydraulic Tank - Horizontal Cylinder Bolt	Drawing no. 17	1
8	Hydraulic Tank Cap	Drawing no. 18	1
9	Table Assembly	From Drawing no. 19A - 26	1
10	Mixer Blades Assembly	From Drawing no. 27A - 29	1
11	Mixing Chamber Assembly	Drawing no. 30	1
12	Vertical Cylinder Assembly	Drawing no. 31 and 32	1
13	Mixing Chamber Mounting Assembly	From Drawing no. 33A - 40	1
14	Vertical Cylinder Mounting Assembly	From Drawing no. 41A - 45	1
15	Guide Tube	Drawing no. 46	1
16	Ram Assembly	Drawing no. 47 and 48	1
17	Mold Assembly	From Drawing no. 49A - 54	1
18	Mold Door Mechanism Assembly	From Drawing no. 55 - 58	1
19	Mixing Chamber Motor Mounting Assembly	From Drawing no. 59A - 63	1
20	Hydraulic Tank - Table Support	Drawing no. 64	1
21	Mixing Blades - Speed Reducer Link	Drawing no. 65 and 66	1

DRW NO 2	**Assembly Name:** Bill of Materials		QTY n/a
PART NO x	**Part Name:** n/a		SCALE n/a
De La Salle University			MATRL n/a
THESIS	Designed by	T.Guanlao, R.Guting, A.Gatmaitan, C.Janairo	Date July 10, 2012
	Drawn by	T.Guanlao	Revised
	Approved by	Dr. Alvin Chua	Units mm

APPENDIX C

Development of an Automated Briquette Machine
De La Salle University



Simulation of Briquette Machine v1.4 - Table Assembly

Date: Tuesday, July 10, 2012
Designer: A. Gatmaitan, T. Guanlao, R. Guting, C. Janairo
Study name:1300
Analysis type: Static

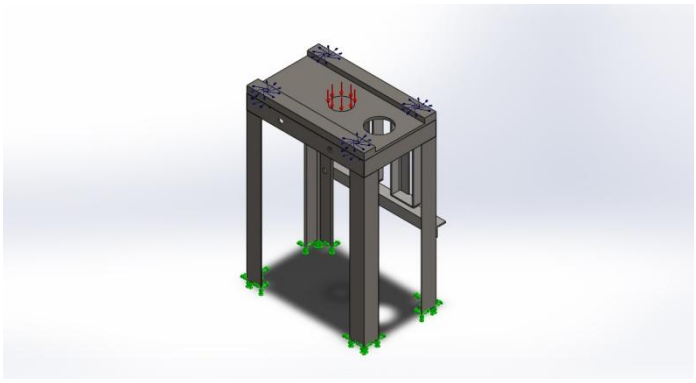
Table of Contents

Description 1
Assumptions 2
Model Information 2
Study Properties 5
Units 5
Material Properties 6
Loads and Fixtures 7
Connector Definitions 8
Contact Information 10
Mesh Information 11
Resultant Forces 12
Study Results 13

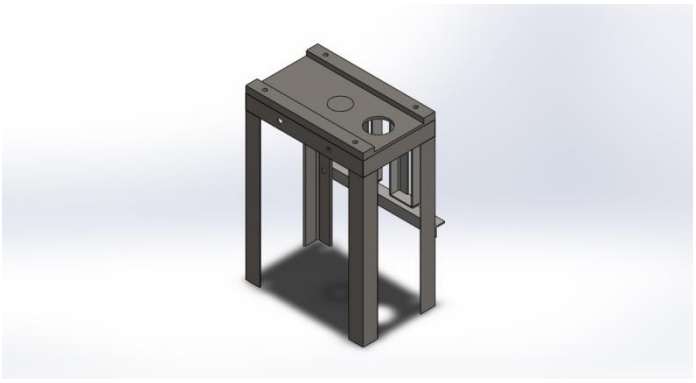
Description

Framework of the briquette machine which will hold most of the machine parts such as the hydraulic cylinder, solenoid valves, and gauges.

Assumptions

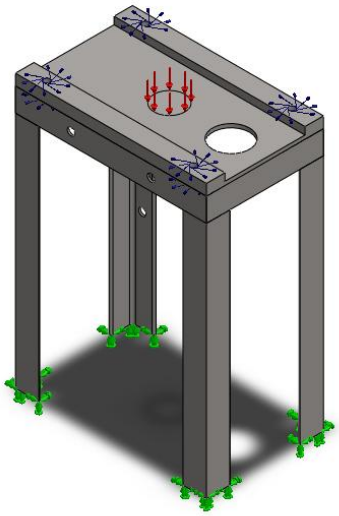


Original Model



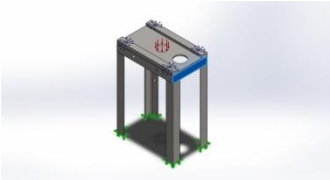
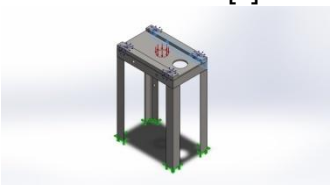
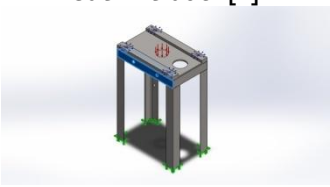
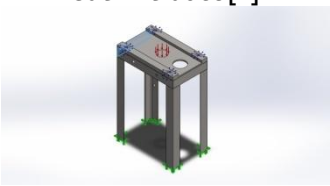
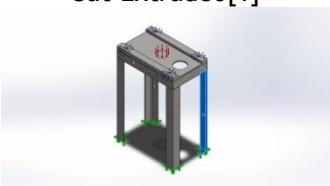
Model Analyzed

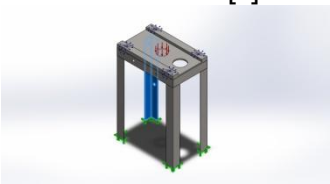
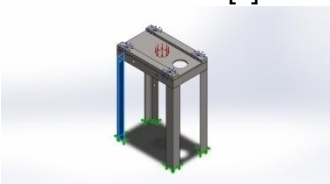
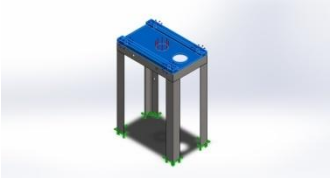
Model Information



Model name: Briquette Machine v1.4 - Table Assembly
Current Configuration: Default<As Machined>

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Cut-Extrude7 	Solid Body	**Mass:0.300489 kg Volume:3.80366e-005 m^3 Density:7900 kg/m^3 Weight:2.94479 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Table Assembly.SLDPRT** Jul 10 12:56:22 2012
Cut-Extrude1[1] 	Solid Body	**Mass:0.524166 kg Volume:6.63501e-005 m^3 Density:7900 kg/m^3 Weight:5.13682 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Table Assembly.SLDPRT** Jul 10 12:56:22 2012
Cut-Extrude1[2] 	Solid Body	**Mass:0.524166 kg Volume:6.63501e-005 m^3 Density:7900 kg/m^3 Weight:5.13682 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Table Assembly.SLDPRT** Jul 10 12:56:22 2012
Cut-Extrude3[1] 	Solid Body	**Mass:0.307993 kg Volume:3.89864e-005 m^3 Density:7900 kg/m^3 Weight:3.01833 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Table Assembly.SLDPRT** Jul 10 12:56:22 2012
Cut-Extrude6[1] 	Solid Body	**Mass:0.707603 kg Volume:8.957e-005 m^3 Density:7900 kg/m^3 Weight:6.93451 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Table Assembly.SLDPRT** Jul 10 12:56:22 2012
Trim/Extend1[2]	Solid Body	**Mass:0.71044 kg Volume:8.99291e-005 m^3 Density:7900 kg/m^3 Weight:6.96231 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Table Assembly.SLDPRT** Jul 10 12:56:22 2012

Cut-Extrude6[2] 	Solid Body	**Mass:0.705633 kg** **Volume:8.93207e-005 m^3** **Density:7900 kg/m^3** **Weight:6.91521 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Table Assembly.SLDPRT** Jul 10 12:56:22 2012
Cut-Extrude3[3] 	Solid Body	**Mass:0.70847 kg** **Volume:8.96798e-005 m^3** **Density:7900 kg/m^3** **Weight:6.94301 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Table Assembly.SLDPRT** Jul 10 12:56:22 2012
Split Line1 	Solid Body	**Mass:4.37645 kg** **Volume:0.000553981 m^3** **Density:7900 kg/m^3** **Weight:42.8892 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Table Assembly.SLDPRT** Jul 10 12:56:22 2012

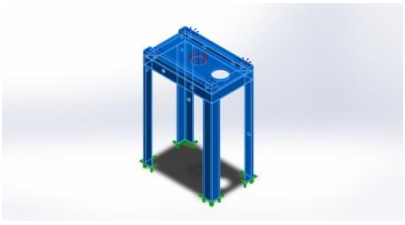
Study Properties

Study name	1300
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	Direct sparse solver
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final))

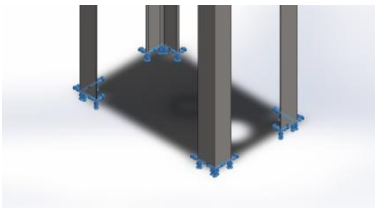
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

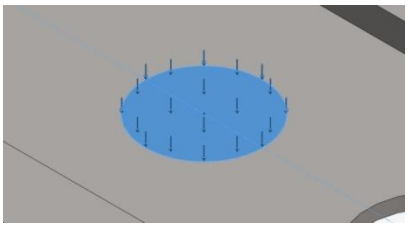
Model Reference	Properties	Components
	**Name:** AISI 1020 **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 3.51571e+008 N/m^2 **Tensile strength:** 4.20507e+008 N/m^2 **Elastic modulus:** 2e+011 N/m^2 **Poisson's ratio:** 0.29 **Mass density:** 7900 kg/m^3 **Shear modulus:** 7.7e+010 N/m^2 **Thermal expansion coefficient:** 1.5e-005 /Kelvin	SolidBody 7(Cut-Extrude7)(Briquette Machine v1.4 - Table Assembly), SolidBody 8(Cut-Extrude1[1])(Briquette Machine v1.4 - Table Assembly), SolidBody 9(Cut-Extrude1[2])(Briquette Machine v1.4 - Table Assembly), SolidBody 10(Cut-Extrude3[1])(Briquette Machine v1.4 - Table Assembly), SolidBody 11(Cut-Extrude6[1])(Briquette Machine v1.4 - Table Assembly), SolidBody 12(Trim/Extend1[2])(Briquette Machine v1.4 - Table Assembly), SolidBody 13(Cut-Extrude6[2])(Briquette Machine v1.4 - Table Assembly), SolidBody 14(Cut-Extrude3[3])(Briquette Machine v1.4 - Table Assembly), SolidBody 15(Split Line1)(Briquette Machine v1.4 - Table Assembly)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 4 face(s) **Type:** Fixed Geometry

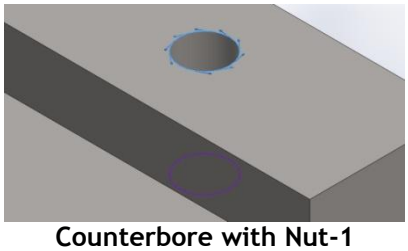
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.000152588	17595.3	-0.000150681	17595.3
Reaction Moment(N-m)	0	0	0	0

Load name	Load Image	Load Details
Pressure-1		**Entities:** 1 face(s) **Type:** Normal to selected face **Value:** 1300 **Units:** psi

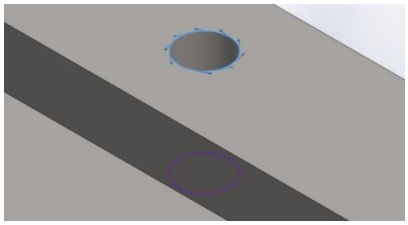
Connector Definitions

Pin/Bolt/Bearing Connector

Model Reference	Connector Details	Strength Details
 Counterbore with Nut-1	**Entities:** 2 edge(s) **Type:** Bolt(Head/Nut diameter)(Counterbore) **Head diameter:** 15 mm **Nut diameter:** 15 mm **Nominal shank diameter:** 10 **Preload (Torque):** 0 **Young's modulus:** 2.1e+011 **Poisson's ratio:** 0.28 **Preload units:** N-m	No Data

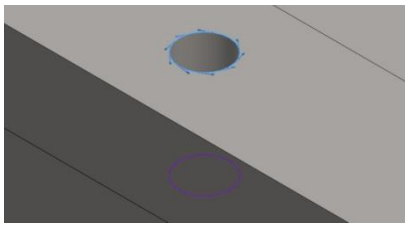
Connector Forces

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	0	0	0
Shear Force (N)	-42.105	2.7284	-50.092	65.495
Bending moment (N-m)	0.07954	-0.001276	-0.0004648	0.079552

Model Reference	Connector Details	Strength Details
 Counterbore with Nut-2	**Entities:** 2 edge(s) **Type:** Bolt(Head/Nut diameter)(Counterbore) **Head diameter:** 15 mm **Nut diameter:** 15 mm **Nominal shank diameter:** 10 **Preload (Torque):** 0 **Young's modulus:** 2.1e+011 **Poisson's ratio:** 0.28 **Preload units:** N-m	No Data

Connector Forces

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	-0	0	0	0
Shear Force (N)	35.013	2.6959	-52.127	62.852
Bending moment (N-m)	0.088669	0.0034849	-0.050049	0.10188



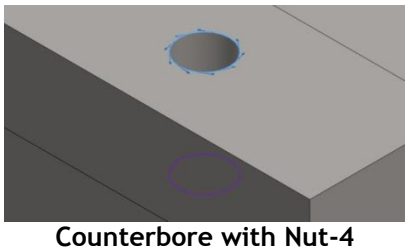
Counterbore with Nut-3

Entities:	2 edge(s)
Type:	Bolt(Head/Nut diameter)(Counterbore)
Head diameter:	15 mm
Nut diameter:	15 mm
Nominal shank diameter:	10
Preload (Torque):	0
Young's modulus:	2.1e+011
Poisson's ratio:	0.28
Preload units:	N-m

No Data

Connector Forces

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	-0	0	-0	0
Shear Force (N)	44.663	3.0235	56.643	72.197
Bending moment (N-m)	-0.17301	0.0004309	0.080116	0.19066



Counterbore with Nut-4

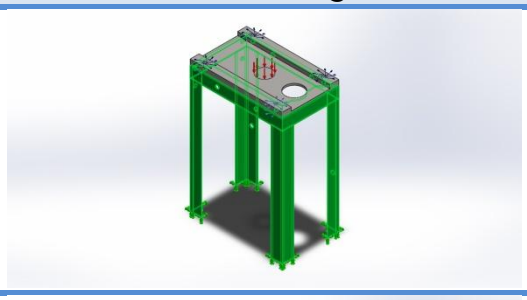
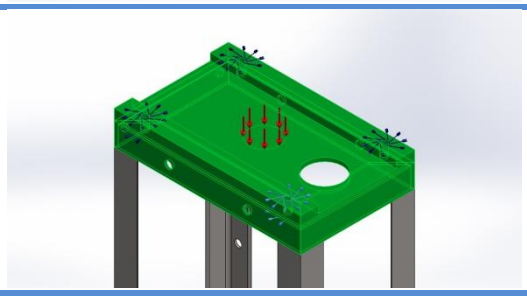
Entities:	2 edge(s)
Type:	Bolt(Head/Nut diameter)(Counterbore)
Head diameter:	15 mm
Nut diameter:	15 mm
Nominal shank diameter:	10
Preload (Torque):	0
Young's modulus:	2.1e+011
Poisson's ratio:	0.28
Preload units:	N-m

No Data

Connector Forces

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	0	-0	0
Shear Force (N)	-40.313	2.8815	54.889	68.164
Bending moment (N-m)	-0.13759	0.00063086	-0.039696	0.1432

Contact Information

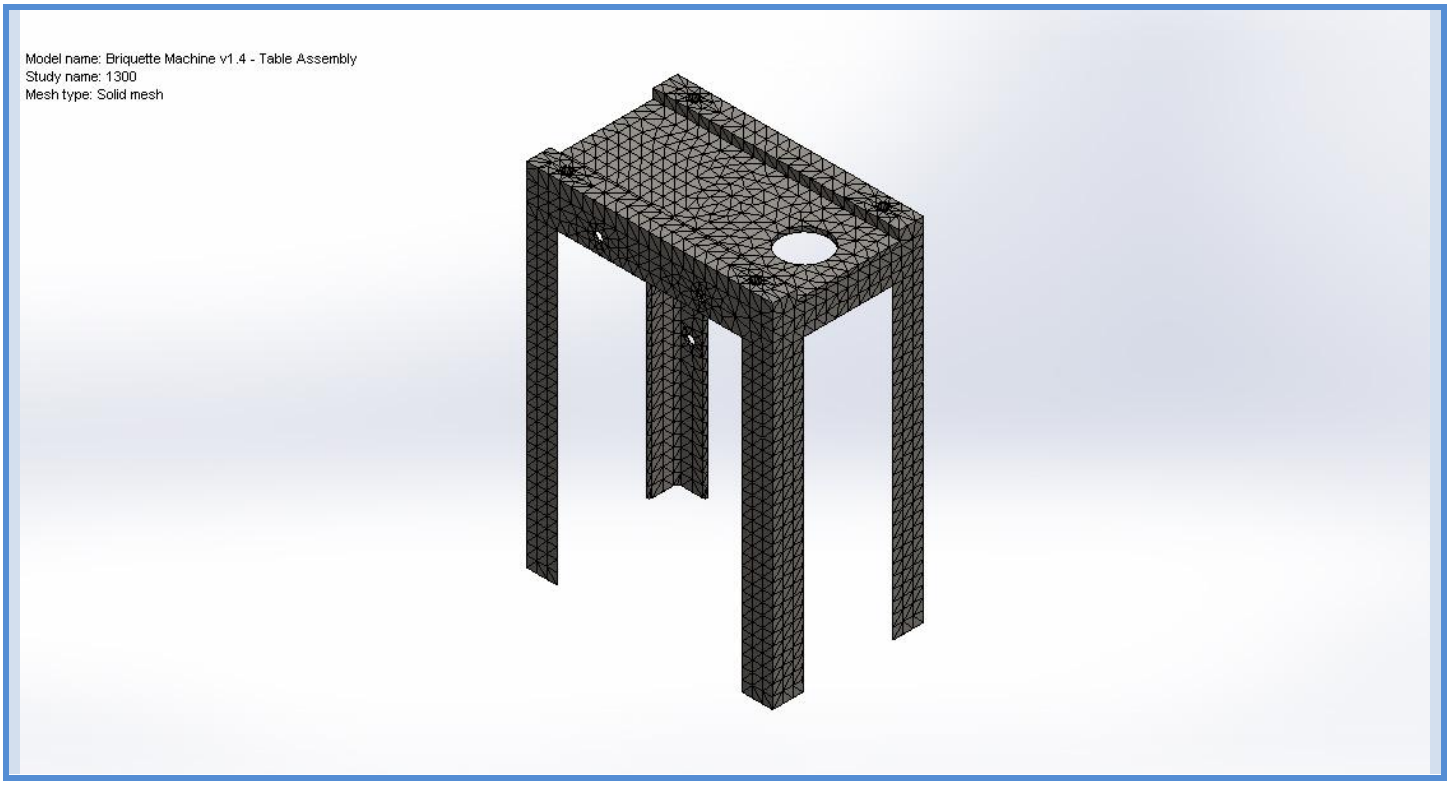
Contact	Contact Image	Contact Properties
Component Contact-1		**Type:** Bonded **Components:** 8 Solid Body (s) **Options:** Compatible mesh
Component Contact-2		**Type:** Bonded **Components:** 5 Solid Body (s) **Options:** Compatible mesh

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	14.3001 mm
Tolerance	0.715006 mm
Mesh Quality	High

Mesh Information - Details

Total Nodes	20905
Total Elements	10546
Maximum Aspect Ratio	22.476
% of elements with Aspect Ratio < 3	39.6
% of elements with Aspect Ratio > 10	1.56
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:20
Computer name:	TRISTAN-PC



Resultant Forces

Reaction Forces

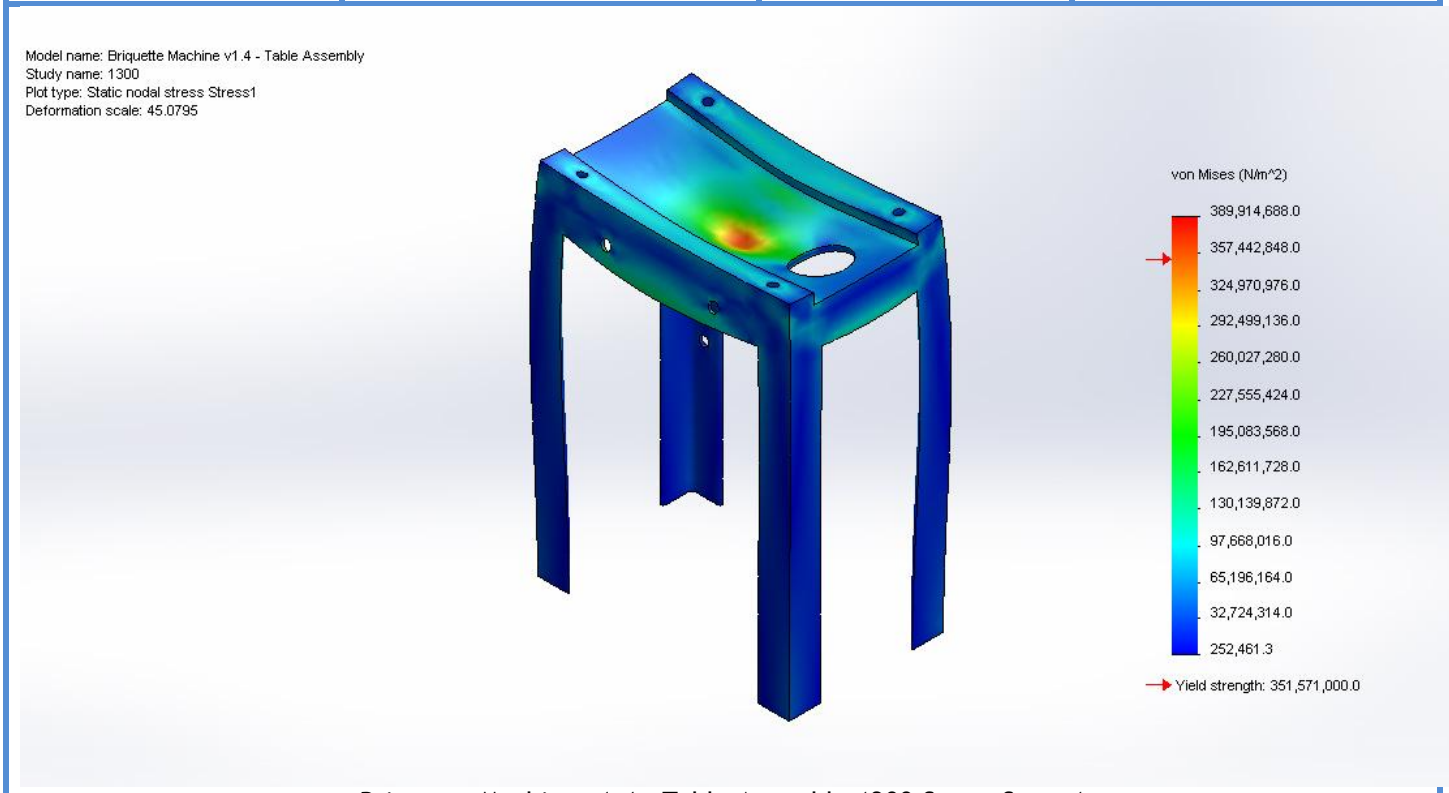
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.000152588	17595.3	-0.000150681	17595.3

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N-m	0	0	0	0

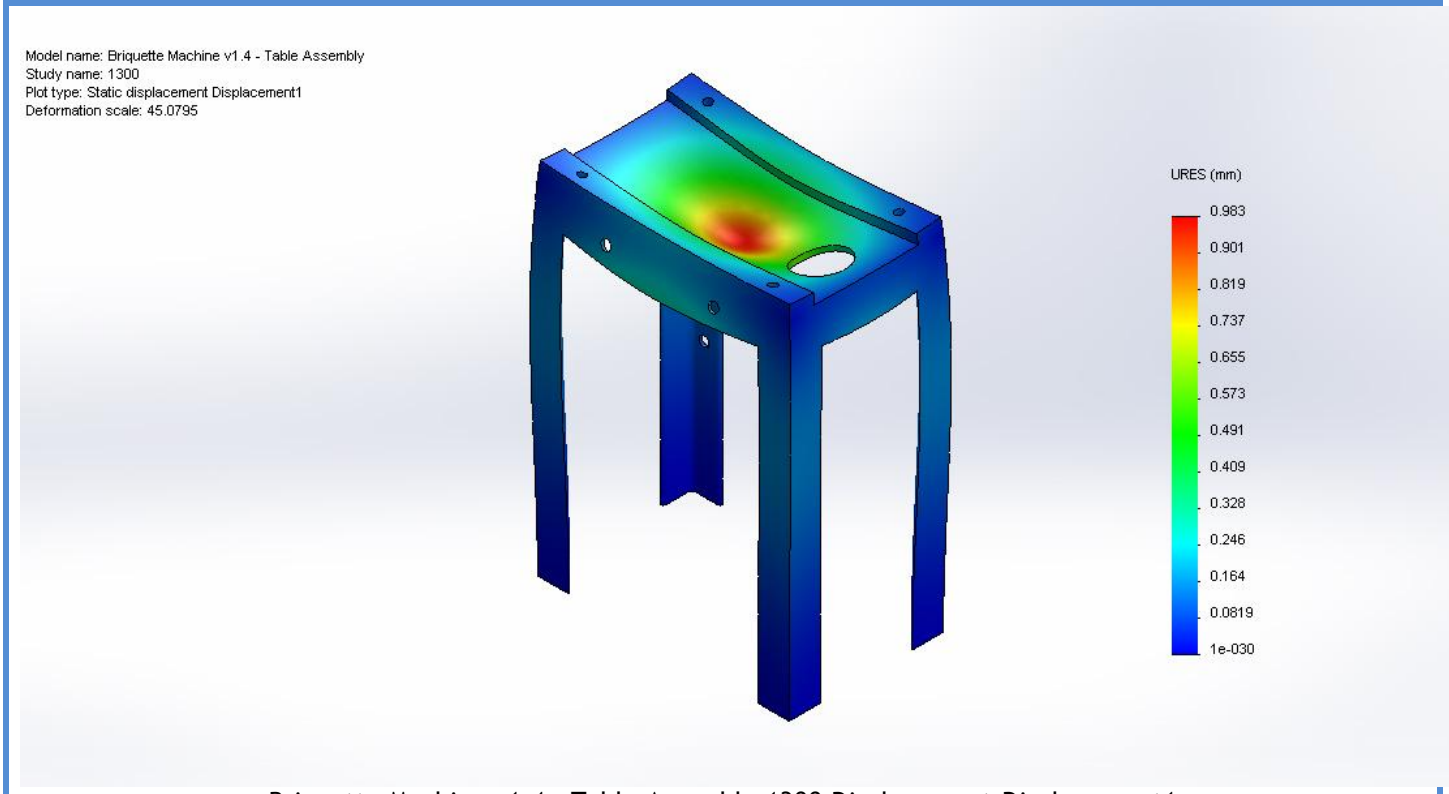
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	252461 N/m^2 Node: 15530	3.89915e+008 N/m^2 Node: 16103



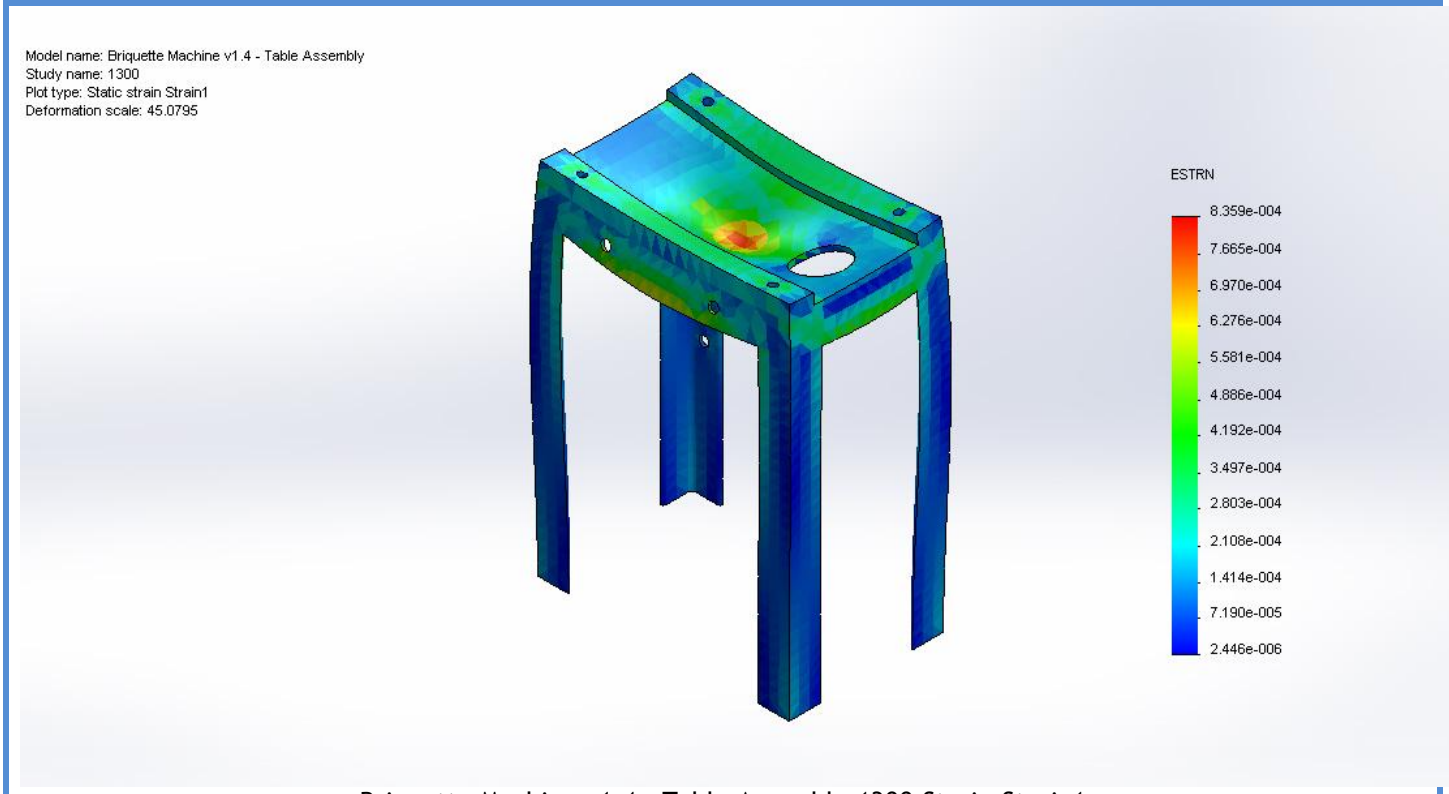
Briquette Machine v1.4 - Table Assembly-1300-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 6694	0.98271 mm Node: 16103



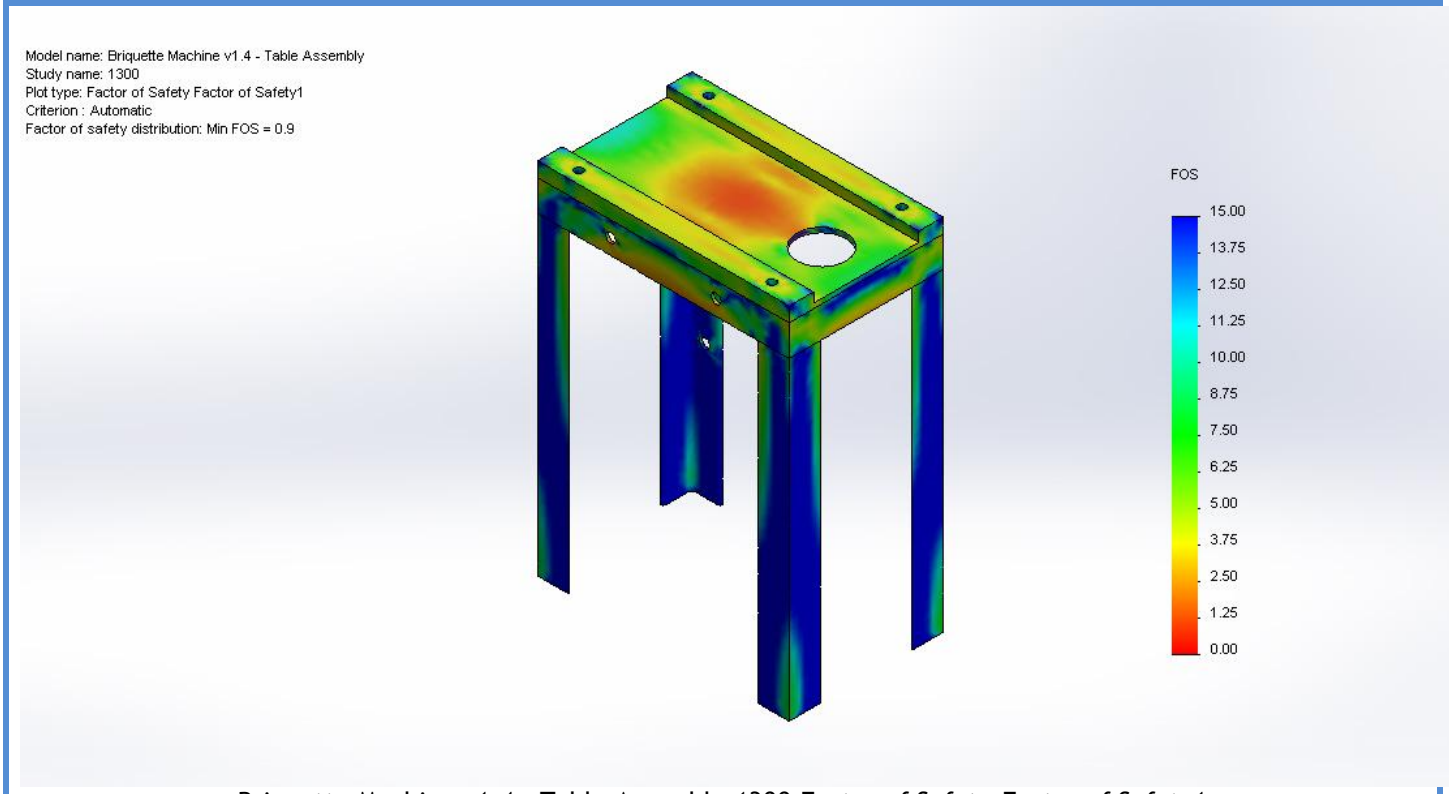
Briquette Machine v1.4 - Table Assembly-1300-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.44593e-006 Element: 6868	0.000835919 Element: 10021



Briquette Machine v1.4 - Table Assembly-1300-Strain-Strain1

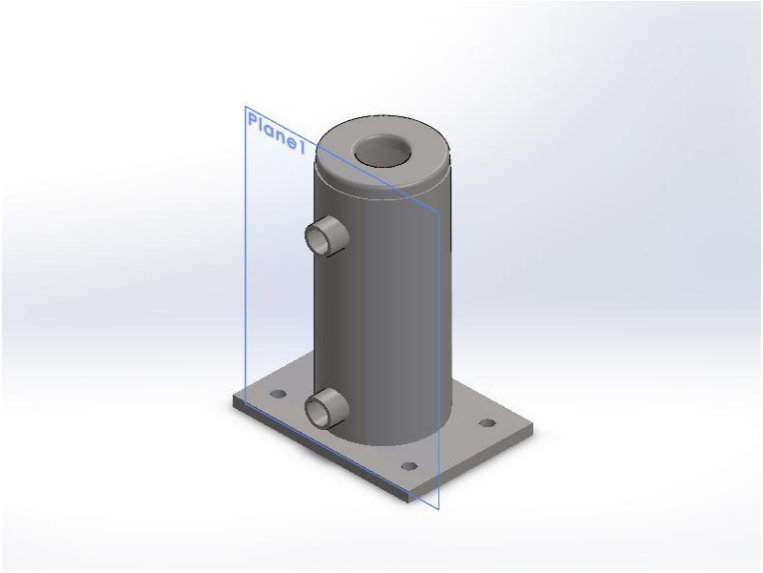
Name	Type	Min	Max
Factor of Safety1	Automatic	0.901661 Node: 16103	1392.57 Node: 15530



Briquette Machine v1.4 - Table Assembly-1300-Factor of Safety-Factor of Safety1

APPENDIX D

Development of an Automated Briquette Machine
De La Salle University



Simulation of Briquette Machine v1.4 - Vertical Cylinder Case

Date: Tuesday, July 10, 2012
Designer: A. Gatmaitan, T. Guanlao, R. Guting, C. Janairo
Study name:1300
Analysis type: Static

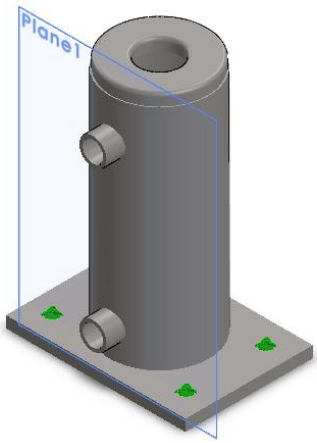
Table of Contents

Description 1
Model Information 2
Study Properties 3
Units 3
Material Properties 4
Loads and Fixtures 4
Contact Information 5
Mesh Information 5
Resultant Forces 6
Study Results 7

Description

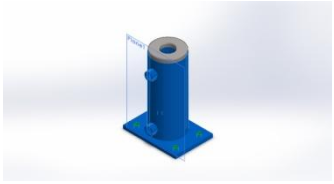
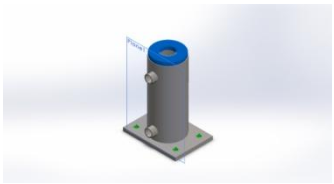
The Vertical Cylinder Case is the one who comes in contact with the biomass on the mold when the pressing is done. It is important that it can sustain the pressure that will be applied during machine operations.

Model Information



Model name: Briquette Machine v1.4 - Vertical Cylinder Case
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Cut-Extrude3 	Solid Body	**Mass:3.42958 kg** **Volume:0.000434124 m^3** **Density:7900 kg/m^3** **Weight:33.6099 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Vertical Cylinder Case.SLDPRT** Jul 08 02:56:14 2012
Fillet1 	Solid Body	**Mass:0.366527 kg** **Volume:4.63958e-005 m^3** **Density:7900 kg/m^3** **Weight:3.59196 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Vertical Cylinder Case.SLDPRT** Jul 08 02:56:14 2012

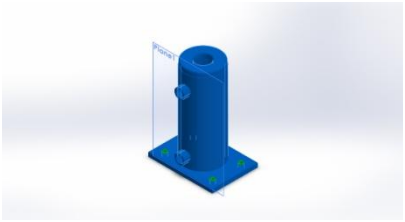
Study Properties

Study name	1300
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final))

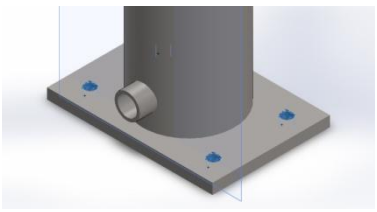
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

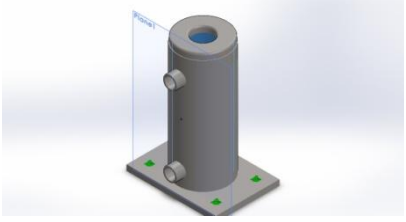
Model Reference	Properties	Components
	**Name:** AISI 1020 **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 3.51571e+008 N/m^2 **Tensile strength:** 4.20507e+008 N/m^2 **Elastic modulus:** 2e+011 N/m^2 **Poisson's ratio:** 0.29 **Mass density:** 7900 kg/m^3 **Shear modulus:** 7.7e+010 N/m^2 **Thermal expansion coefficient:** 1.5e-005 /Kelvin	SolidBody 1(Cut-Extrude3)(Briquette Machine v1.4 - Vertical Cylinder Case), SolidBody 2(Fillet1)(Briquette Machine v1.4 - Vertical Cylinder Case)
Curve Data:N/A		

Loads and Fixtures

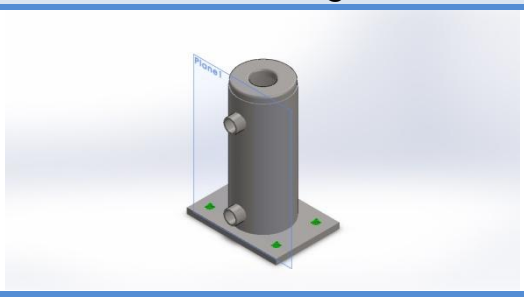
Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 4 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.233231	0.266266	4690.47	4690.47
Reaction Moment(N-m)	0	0	0	0

Load name	Load Image	Load Details
Pressure-1		**Entities:** 1 face(s) **Type:** Normal to selected face **Value:** 1300 **Units:** psi

Contact Information

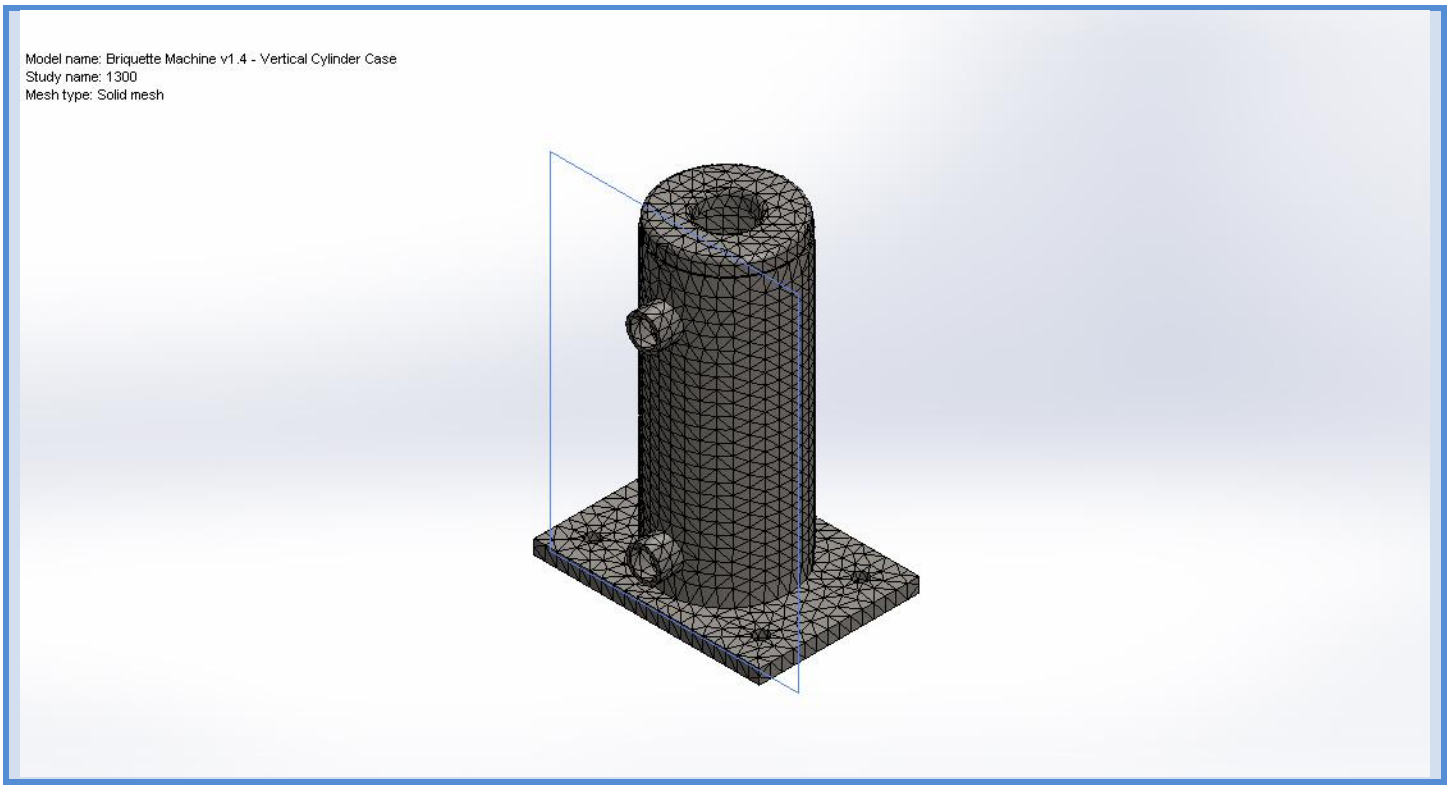
Contact	Contact Image	Contact Properties
Global Contact		**Type:** Bonded **Components:** 1 component(s) **Options:** Compatible mesh

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	7.98994 mm
Tolerance	0.399497 mm
Mesh Quality	High

Mesh Information - Details

Total Nodes	17769
Total Elements	9392
Maximum Aspect Ratio	9.8815
% of elements with Aspect Ratio < 3	96.4
% of elements with Aspect Ratio > 10	0
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:09
Computer name:	TRISTAN-PC



Resultant Forces

Reaction Forces

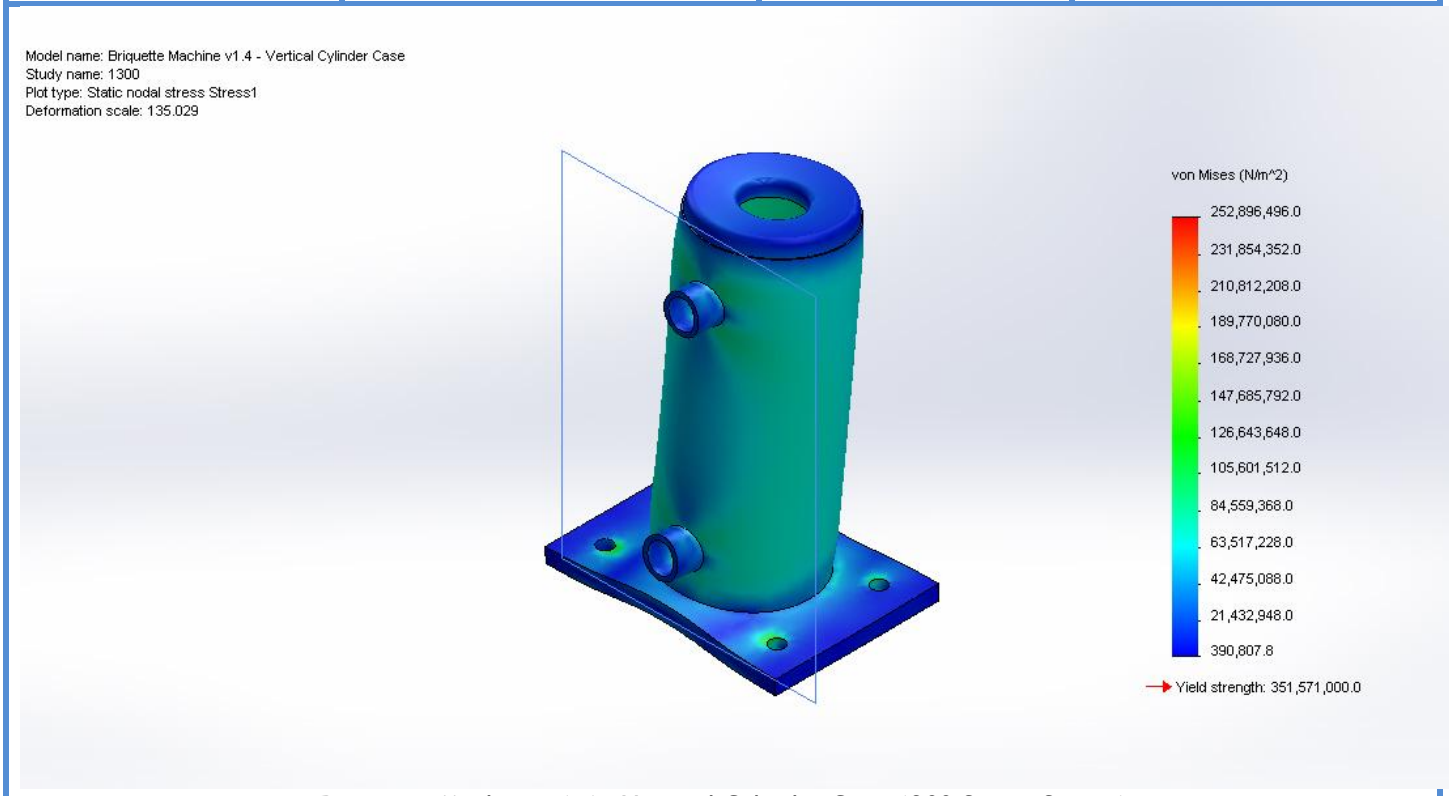
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.233231	0.266266	4690.47	4690.47

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N-m	0	0	0	0

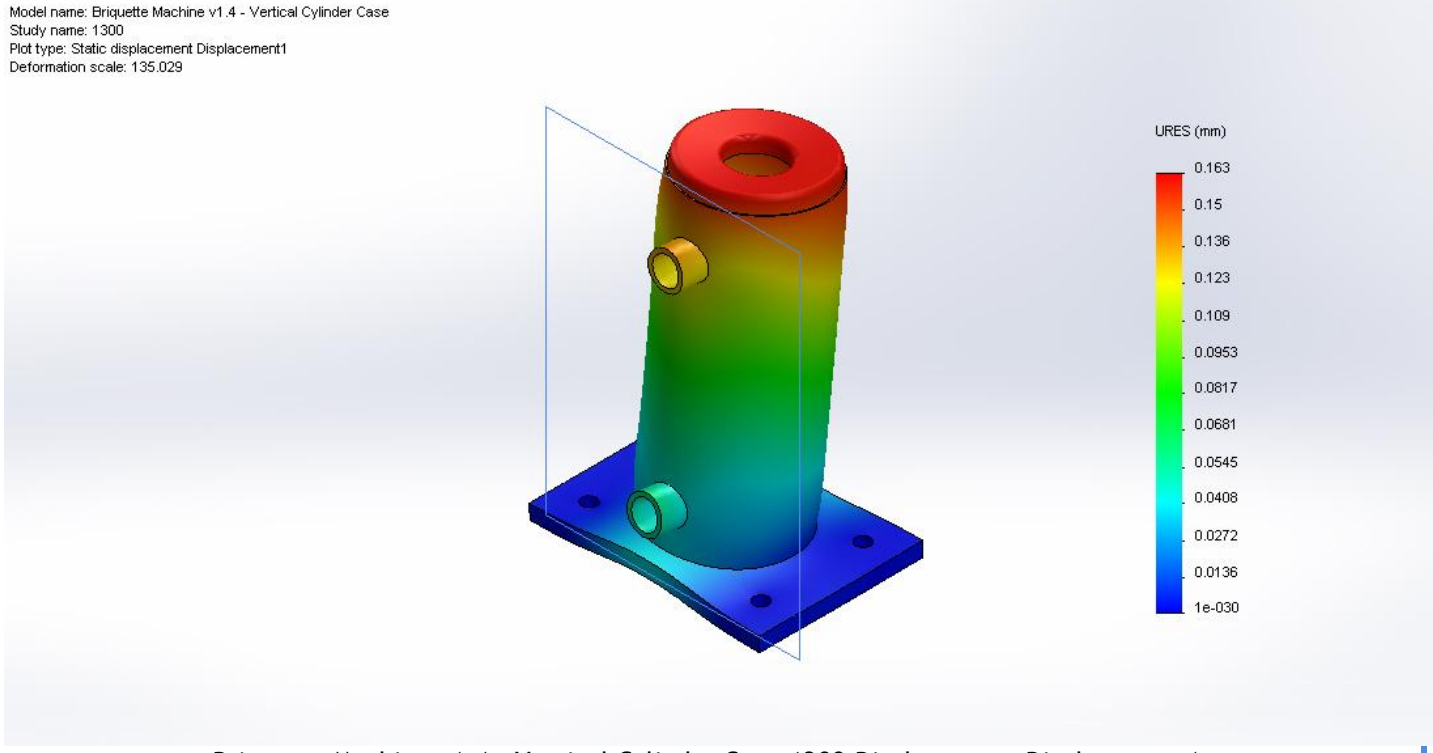
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	390808 N/m^2 Node: 1847	2.52896e+008 N/m^2 Node: 12009



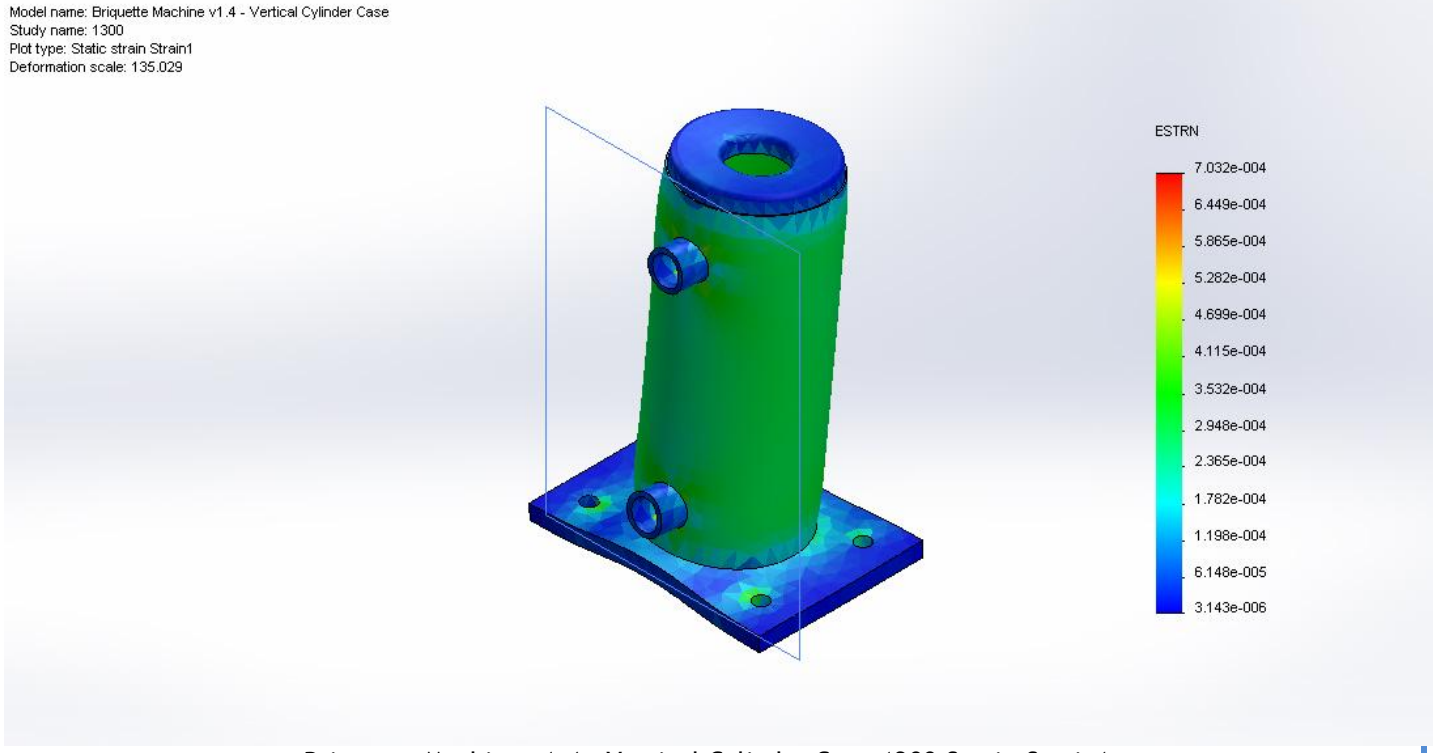
Briquette Machine v1.4 - Vertical Cylinder Case-1300-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 127	0.163384 mm Node: 16951



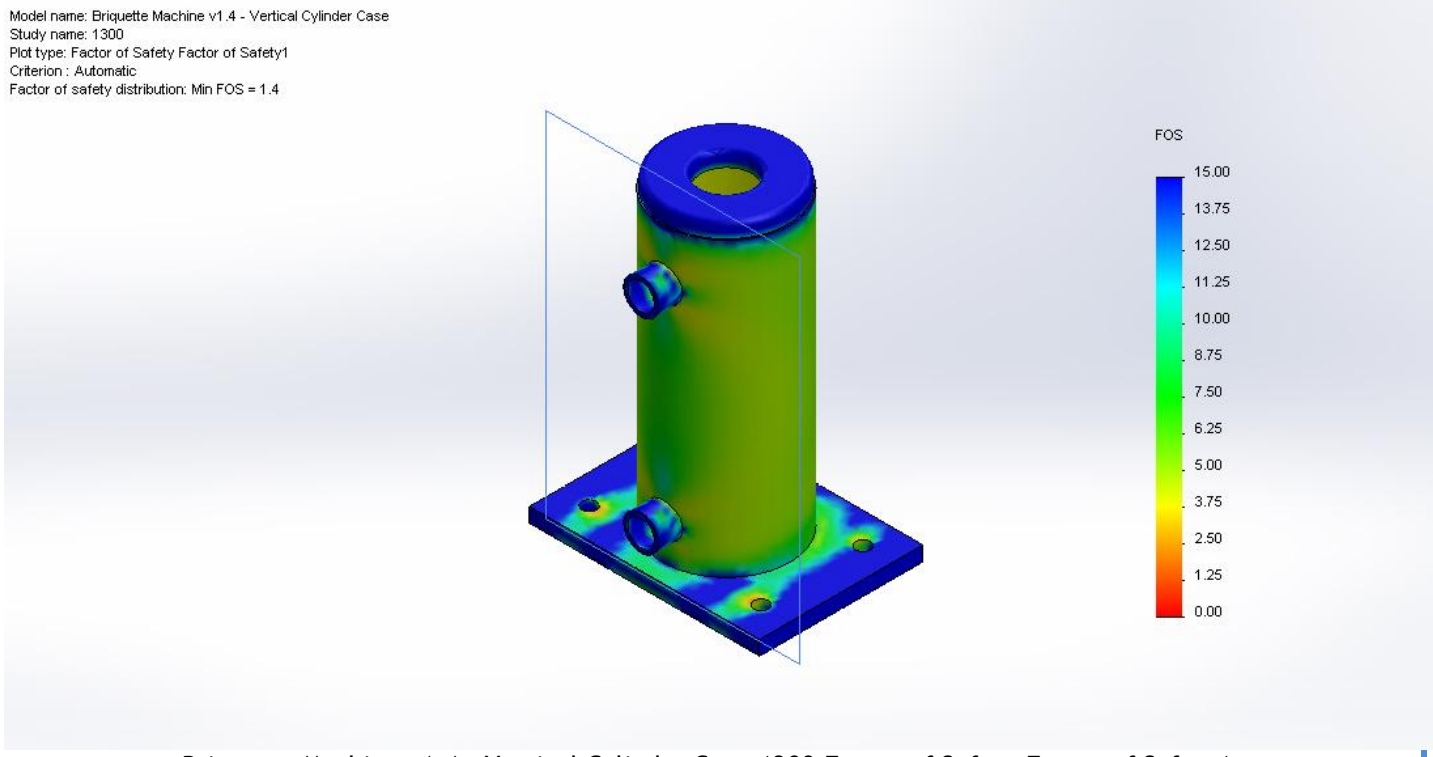
Briquette Machine v1.4 - Vertical Cylinder Case-1300-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	3.14347e-006 Element: 6933	0.000703229 Element: 7816



Briquette Machine v1.4 - Vertical Cylinder Case-1300-Strain-Strain1

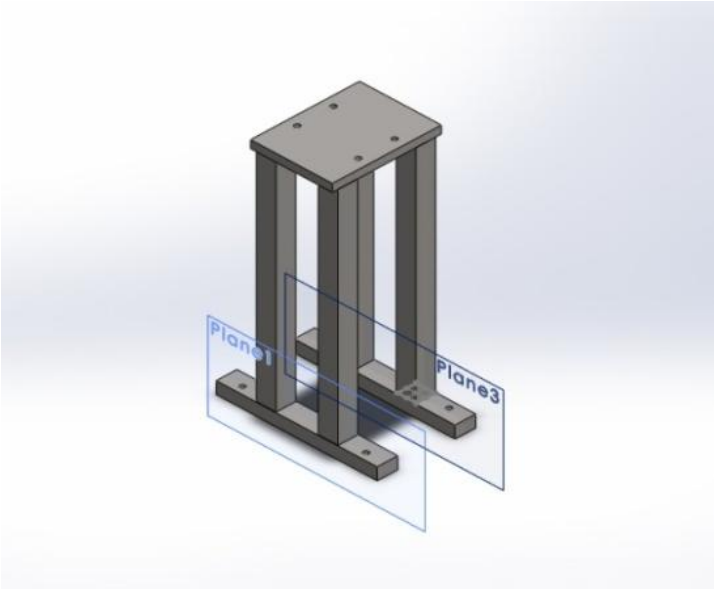
Name	Type	Min	Max
Factor of Safety1	Automatic	1.39018 Node: 12009	899.601 Node: 1847



Briquette Machine v1.4 - Vertical Cylinder Case-1300-Factor of Safety-Factor of Safety1

APPENDIX E

Development of an Automated Briquette Machine
De La Salle University



Description

This part holds the hydraulic cylinder that applies the needed pressure on the biomass briquette. Different analyses were conducted on the two "feet" of this part, wherein most of the stress is concentrated.

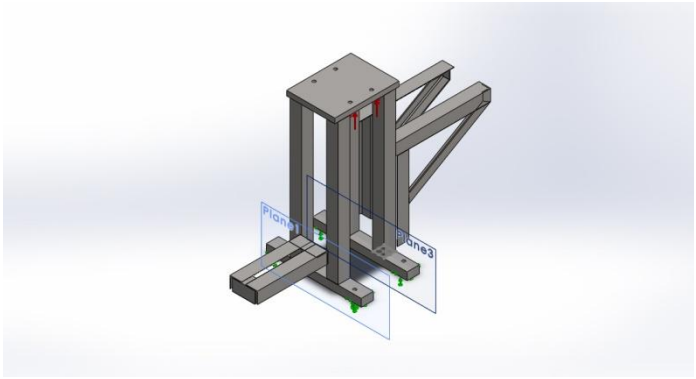
Simulation of Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly

Date: Tuesday, July 10, 2012
Designer: A. Gatmaitan, T. Guanlao, R. Guting, C. Janairo
Study name: 1300
Analysis type: Static

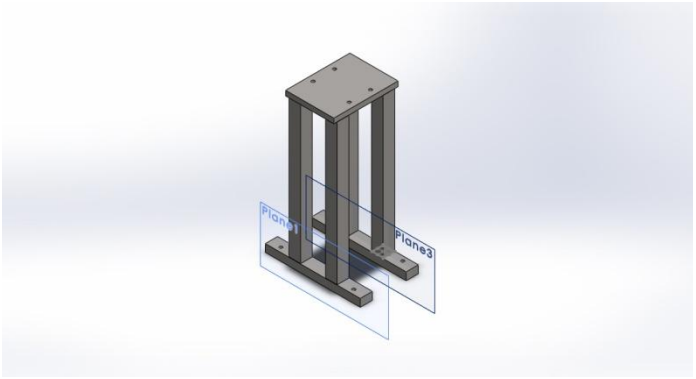
Table of Contents

Description 1
Assumptions 2
Model Information 2
Study Properties 5
Units 5
Material Properties 6
Loads and Fixtures 7
Contact Information 7
Mesh Information 8
Resultant Forces 9
Study Results 10

Assumptions

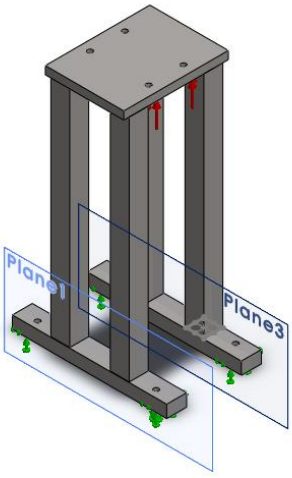


Original Model



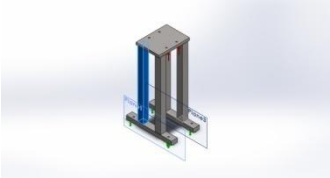
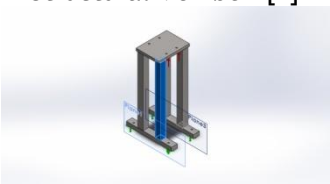
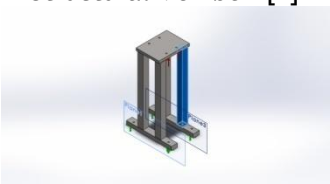
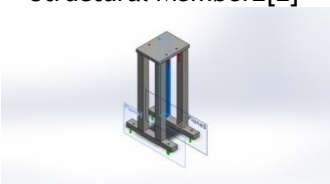
Model Analyzed

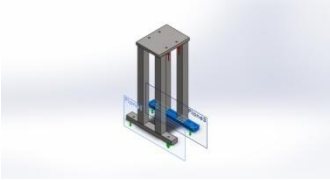
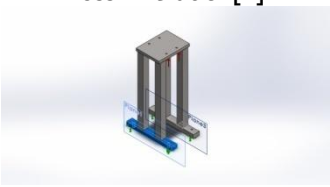
Model Information



Model name: Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly
Current Configuration: Default<As Machined>

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Structural Member1[1] 	Solid Body	**Mass:1.25173 kg Volume:0.000158447 m^3 Density:7900 kg/m^3 Weight:12.267 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly.SLDPRT** Jul 09 21:57:02 2012
Structural Member1[2] 	Solid Body	**Mass:1.25173 kg Volume:0.000158447 m^3 Density:7900 kg/m^3 Weight:12.267 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly.SLDPRT** Jul 09 21:57:02 2012
Structural Member2[1] 	Solid Body	**Mass:1.25173 kg Volume:0.000158447 m^3 Density:7900 kg/m^3 Weight:12.267 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly.SLDPRT** Jul 09 21:57:02 2012
Structural Member2[2] 	Solid Body	**Mass:1.25173 kg Volume:0.000158447 m^3 Density:7900 kg/m^3 Weight:12.267 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly.SLDPRT** Jul 09 21:57:02 2012
Split Line1	Solid Body	**Mass:4.15355 kg Volume:0.000525766 m^3 Density:7900 kg/m^3 Weight:40.7048 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly.SLDPRT** Jul 09 21:57:02 2012

Boss-Extrude1[1] 	Solid Body	**Mass:2.41798 kg** **Volume:0.000306073 m^3** **Density:7900 kg/m^3** **Weight:23.6962 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly.SLDPRT** Jul 09 21:57:02 2012
Boss-Extrude1[2] 	Solid Body	**Mass:2.41798 kg** **Volume:0.000306073 m^3** **Density:7900 kg/m^3** **Weight:23.6962 N**	**F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final)\Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly.SLDPRT** Jul 09 21:57:02 2012

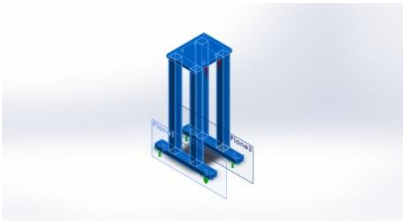
Study Properties

Study name	1000
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	Direct sparse solver
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (F:\School Files\THESIS\Machine Essentials\Briquette Machine Design v1.4 (Final))

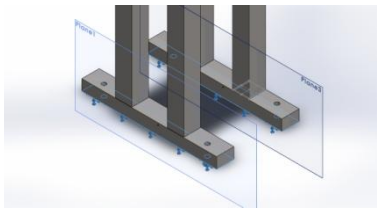
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

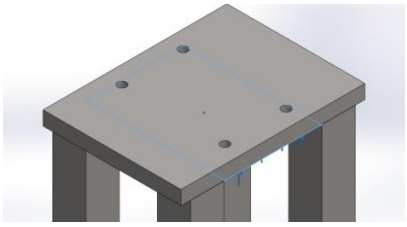
Model Reference	Properties	Components
	**Name:** AISI 1020 **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 3.51571e+008 N/m^2 **Tensile strength:** 4.20507e+008 N/m^2 **Elastic modulus:** 2e+011 N/m^2 **Poisson's ratio:** 0.29 **Mass density:** 7900 kg/m^3 **Shear modulus:** 7.7e+010 N/m^2 **Thermal expansion coefficient:** 1.5e-005 /Kelvin	SolidBody 2(Structural Member1[1])(Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly), SolidBody 4(Structural Member1[2])(Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly), SolidBody 5(Structural Member2[1])(Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly), SolidBody 6(Structural Member2[2])(Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly), SolidBody 7(Split Line1)(Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly), SolidBody 17(Boss-Extrude1[1])(Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly), SolidBody 19(Boss-Extrude1[2])(Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly)
Curve Data:N/A		

Loads and Fixtures

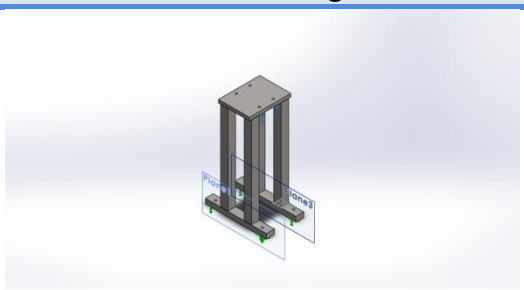
Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 2 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.000510216	-155386	-0.00145245	155386
Reaction Moment(N-m)	0	0	0	0

Load name	Load Image	Load Details
Pressure-1		**Entities:** 1 face(s) **Type:** Normal to selected face **Value:** 1300 **Units:** psi

Contact Information

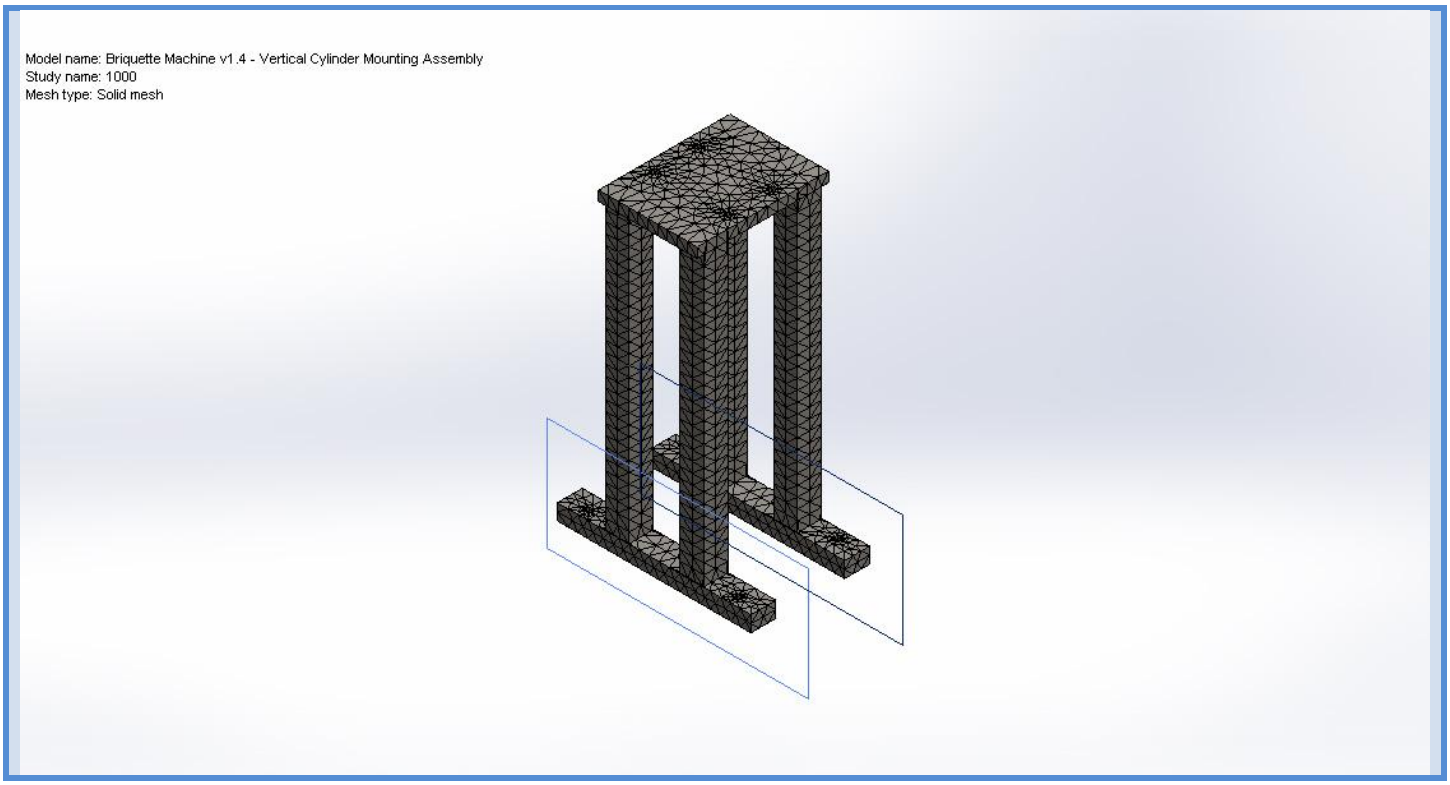
Contact	Contact Image	Contact Properties
Global Contact		**Type:** Bonded **Components:** 1 component(s) **Options:** Compatible mesh

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	16.6262 mm
Tolerance	0.83131 mm
Mesh Quality	High

Mesh Information - Details

Total Nodes	19329
Total Elements	10169
Maximum Aspect Ratio	23.264
% of elements with Aspect Ratio < 3	35
% of elements with Aspect Ratio > 10	1.98
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:22
Computer name:	TRISTAN-PC



Resultant Forces

Reaction Forces

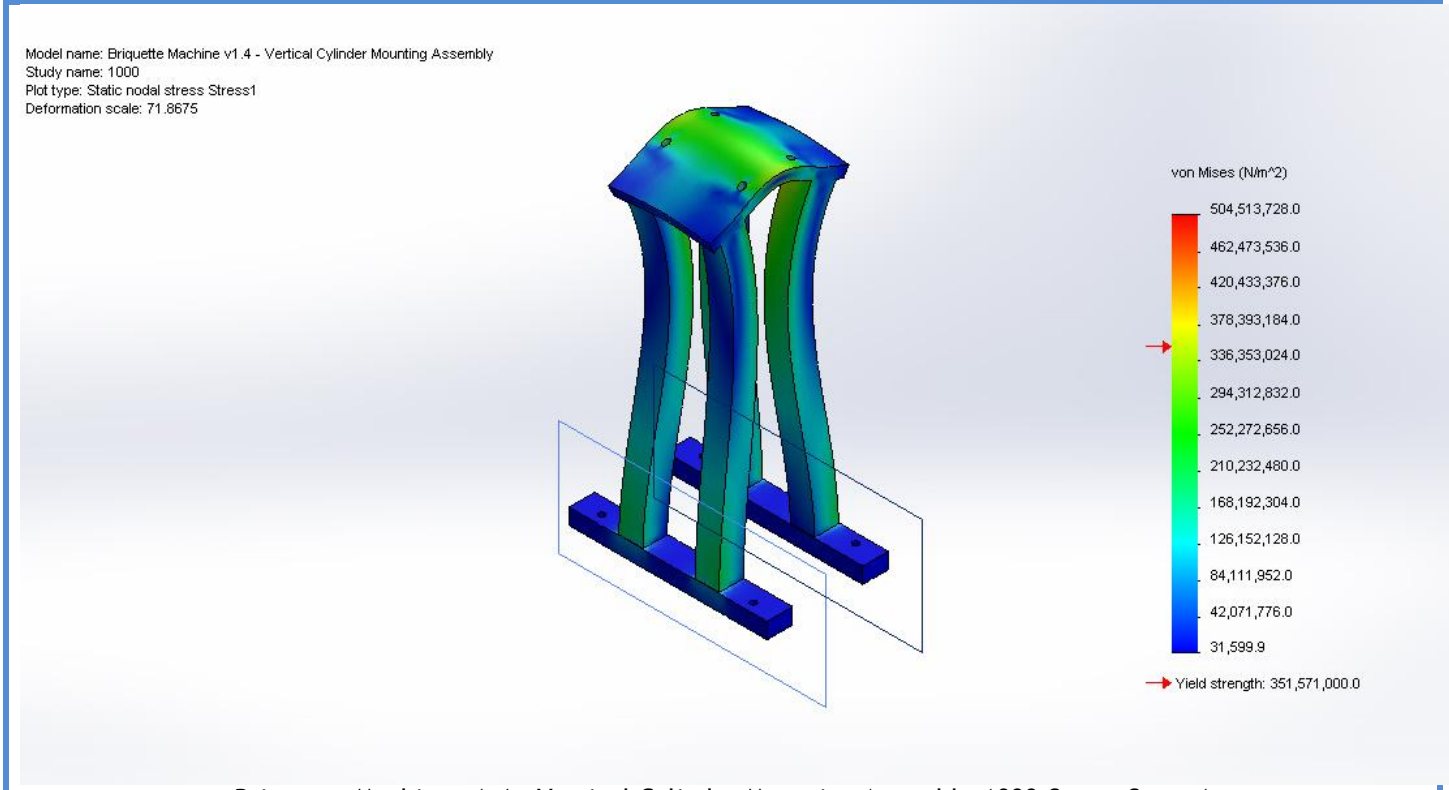
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.000510216	-155386	-0.00145245	155386

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N-m	0	0	0	0

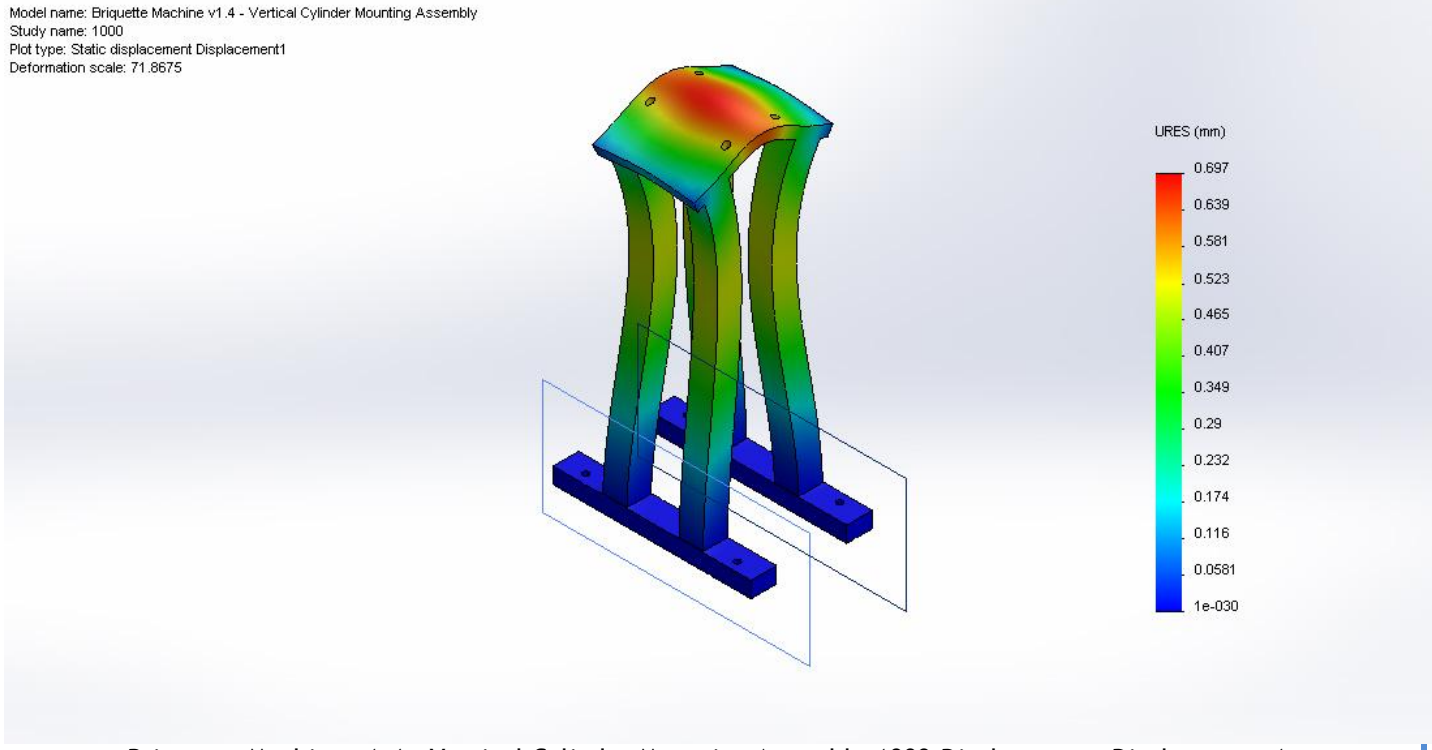
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	31599.9 N/m^2 Node: 16298	5.04514e+008 N/m^2 Node: 14380



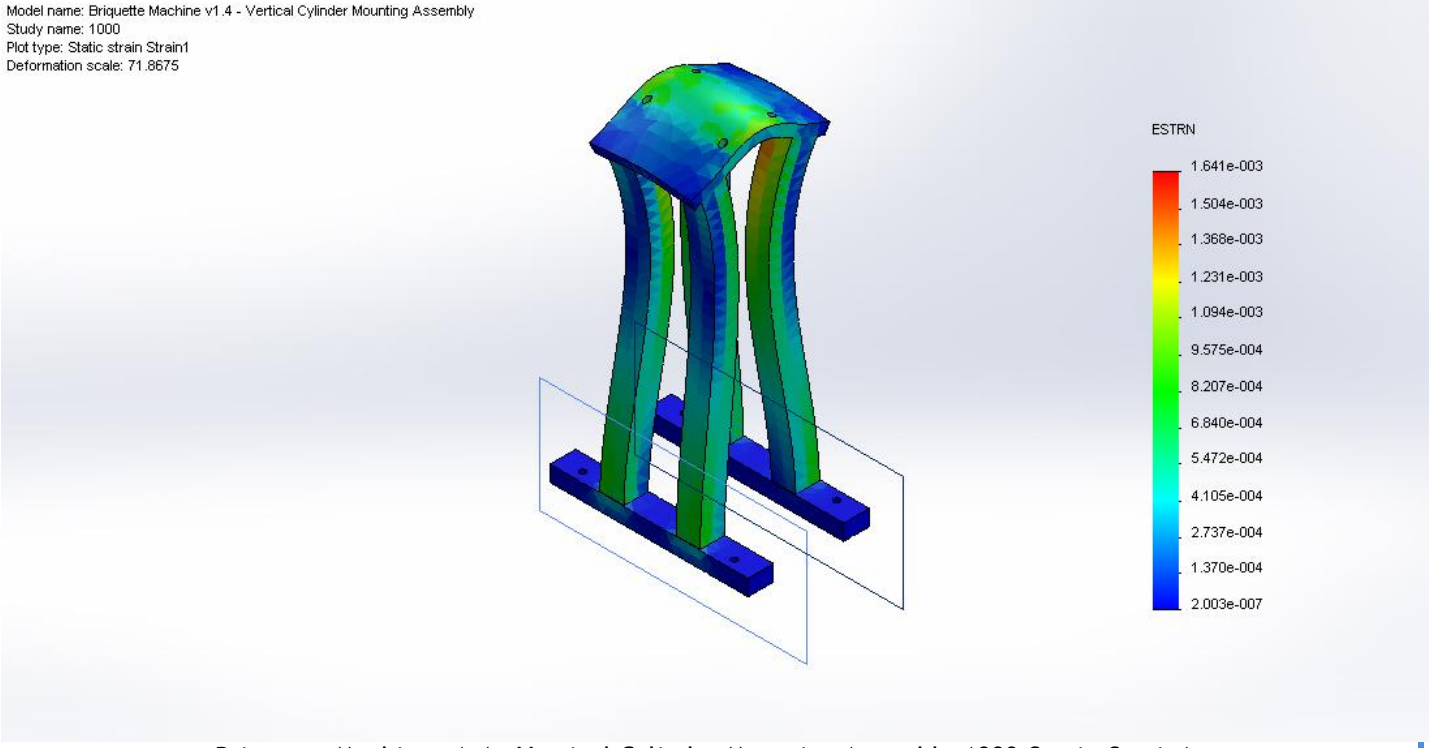
Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly-1000-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 14729	0.697117 mm Node: 12385



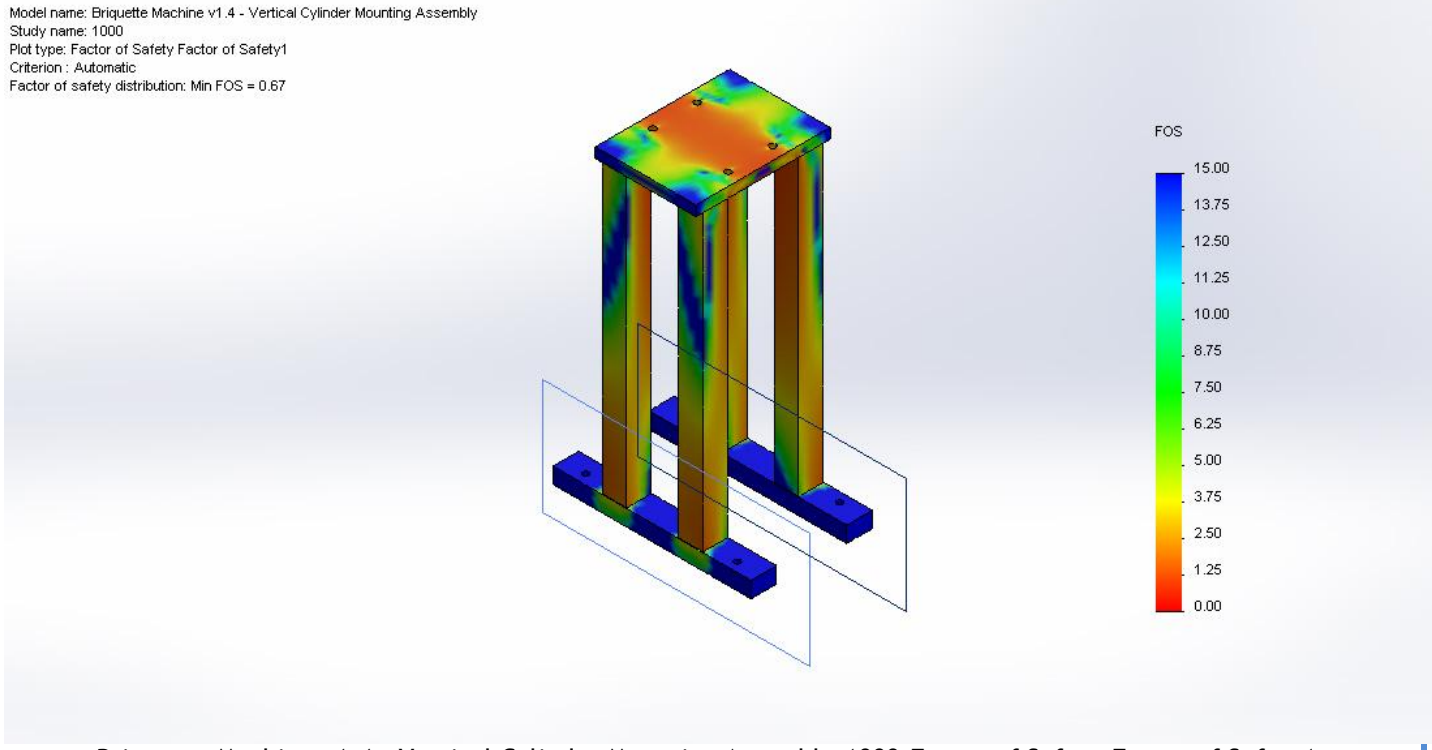
Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly-1000-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.00253e-007 Element: 7795	0.00164121 Element: 1338



Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly-1000-Strain-Strain1

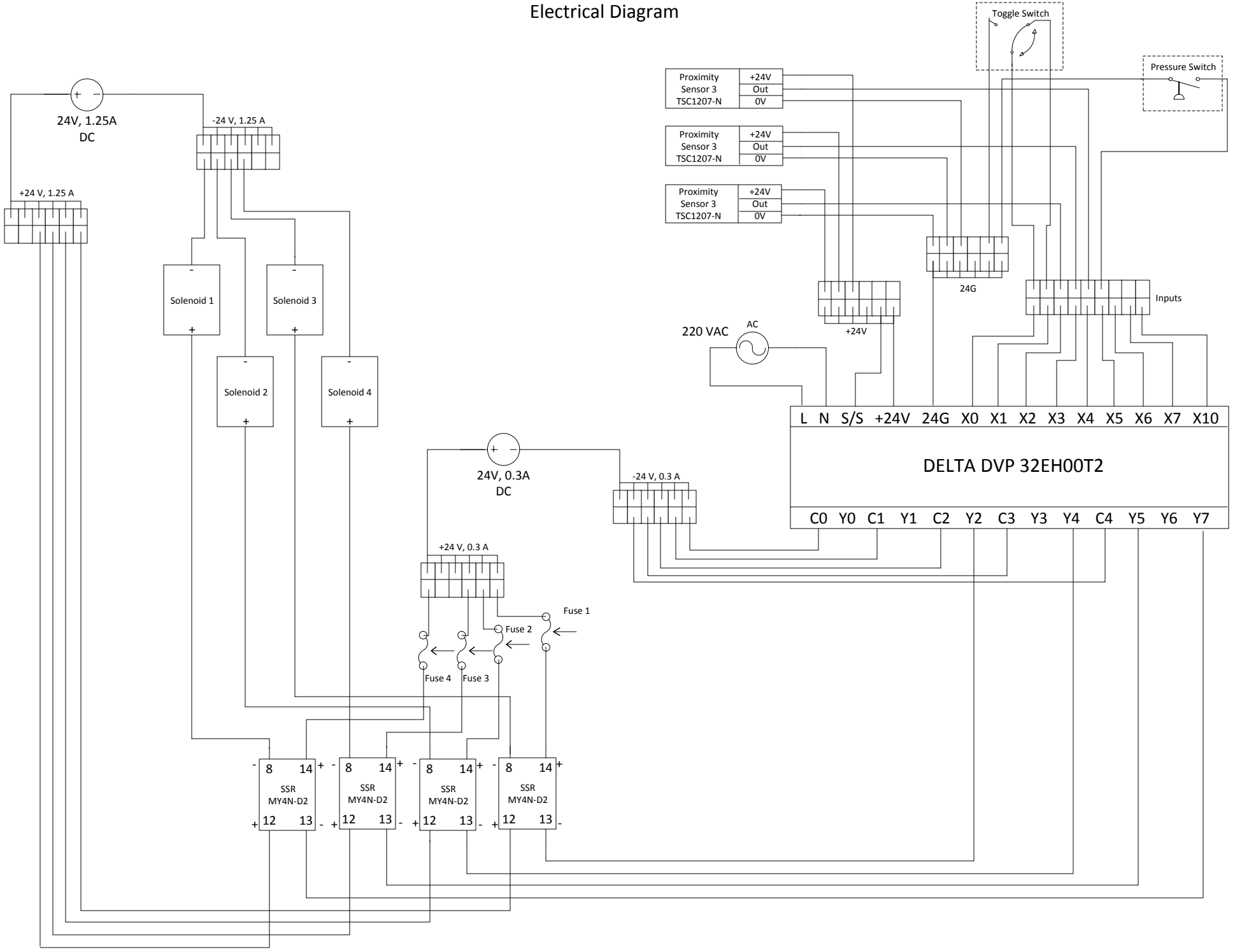
Name	Type	Min	Max
Factor of Safety1	Automatic	0.673171 Node: 185	11125.7 Node: 16298



Briquette Machine v1.4 - Vertical Cylinder Mounting Assembly-1000-Factor of Safety-Factor of Safety1

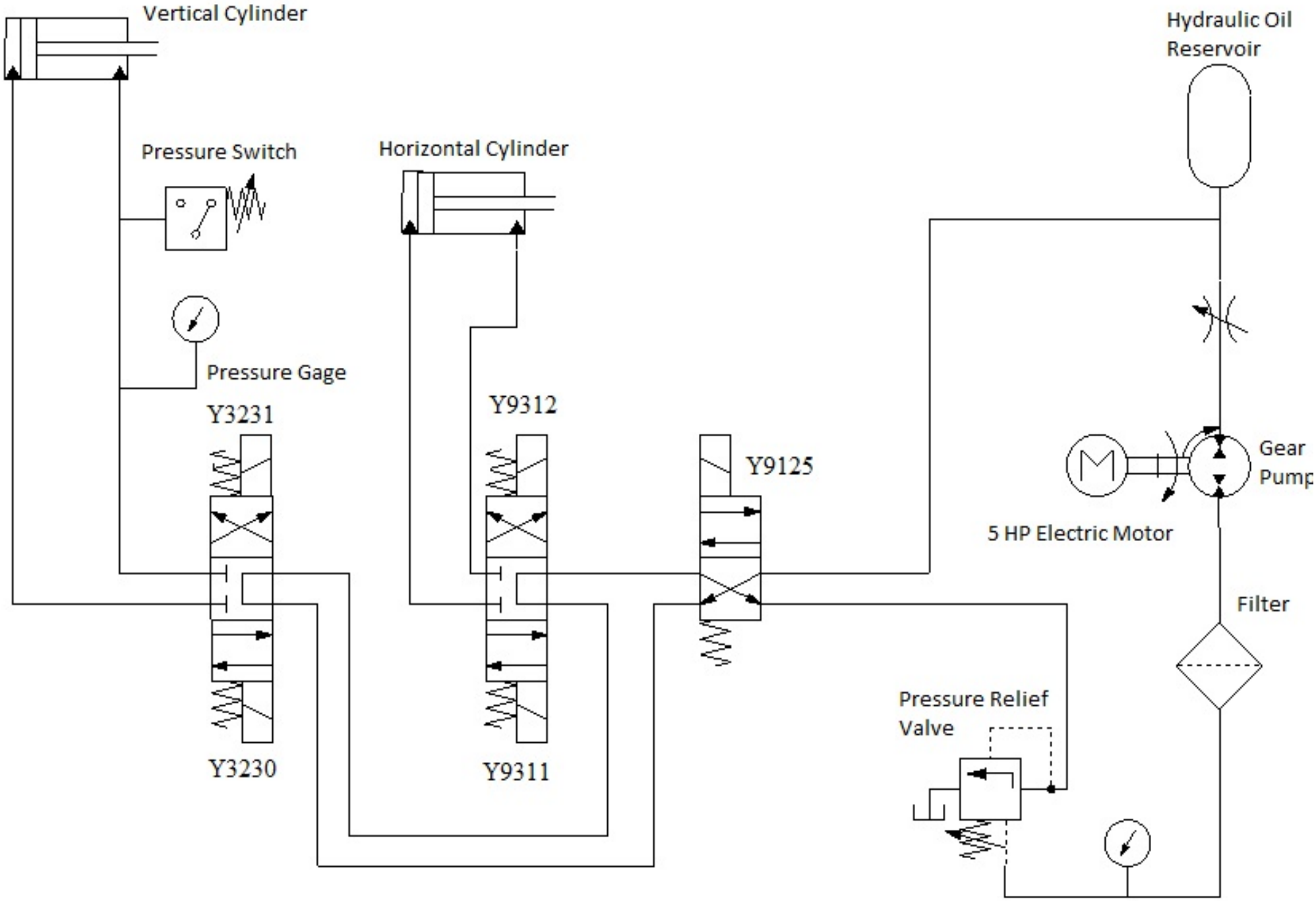
APPENDIX F

Electrical Diagram



APPENDIX G

Hydraulic Circuit Diagram



APPENDIX H

2006-10-24

5011650900-H2E0

http://www.delta.com.tw/industrialautomation/

DVP-EH2

High-Speed, Multi-Functional Programmable Logic Controller

Instruction Sheet

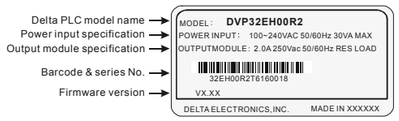
Warning

- ✓ *This instruction sheet only provides introductory information on electrical specification, functions, wiring, trouble-shooting and peripherals. For detailed information on programming and instructions, please refer to "DVP-PLC Application Manual: Programming". For how to purchase its peripheral devices, please refers to the manual enclosed with the product.*
- ✓ *DVP-EH2 is an OPEN-TYPE device and therefore should be installed in an enclosure free of airborne dust, humidity, electric shock and vibration. The enclosure should prevent non-maintenance staff from operating the device (e.g. key or specific tools are required for opening the enclosure) in case danger and damage on the device may occur.*
- ✓ *DO NOT connect input AC power supply to any of the I/O terminals; otherwise serious damage may occur. Check all the wiring again before switching on the power and Do NOT tough any terminal when the power is switched on. Make sure the groud terminal ⏚ is correctly grounded in order to prevent electromagnetic interference.*

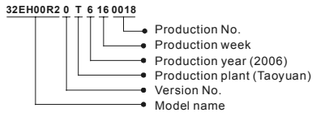
❶ Introduction

1.1 Model Explanation & Peripherals

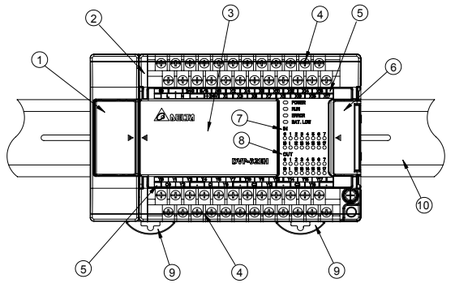
❖ Nameplate Explanation



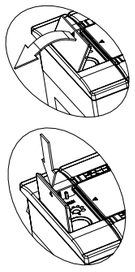
❖ Model/Serial No. Explanation



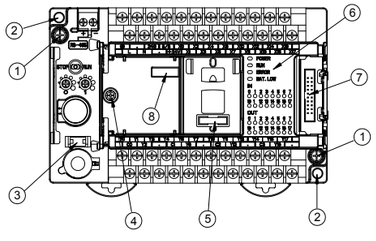
1.2 Product Profile & Outline



Open COM1 cover

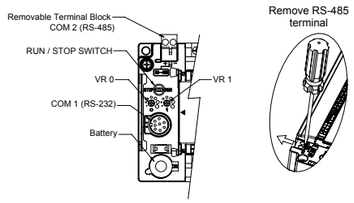


① Communication port cover	⑥ Extension module connection port cover
② I/O terminal cover	⑦ Input indicator
③ Function card/memory card cover	⑧ Output indicator
④ I/O terminals	⑨ DIN rail clip
⑤ I/O terminal No.	⑩ DIN rail (35mm)



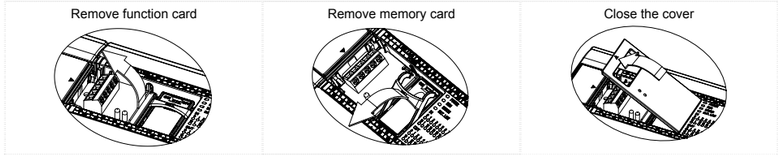
Open COM2 cover

① Mounting screw	⑤ Memory card port
② Direct mounting hole	⑥ POWER/RUN/BAT.LOW/ERROR indicator
③ Battery socket	⑦ Extension module connection port
④ Function card mounting hole	



Part	Description
COM2 (RS-485)	For both master & slave modes
RUN/STOP switch	PLC RUN/STOP control
VR0	Enable M1178/corresponding value of D1178
VR1	Enable M1179/corresponding value of D1179
COM1 (RS-232)	For slave mode
Battery	Shall be changed within 1 min.

1.3 Installation of function card/memory card (optional accessories)



For details, see the instruction sheets of these accessories.

❷ Electrical Specifications

Item \ Model	16EH00□2	20EH00□2	32EH00□2	40EH00□2	48EH00□2	64EH00□2	80EH00□2
Power supply voltage	100 ~240VAC (-15% ~ 10%); 50/60Hz ± 5%						
Fuse capacity	2A/250VAC						
Power consumption	50VA	50VA	60VA	60VA	60VA	80VA	80VA
DC24V current supply	500mA	500mA	500mA	500mA	500mA	500mA	500mA
Power protection	DC24V; output short-circuited						
Withstand voltage	1500VAC (Primary-Secondary); 1500VAC (Primary-PE); 500VAC (Secondary-PE)						
Insulation resistance	＞5 MΩ (all I/O point-to-ground: 500VDC)						
Noise immunity	ESD: 8KV Air Discharge; EFT: Power Line: 2KV, Digital I/O: 1KV, Analog & Communication I/O: 250V Damped-Oscillatory Wave: Power Line: 1KV, Digital I/O: 1KV, RS: 26MHz ~ 1GHz, 10V/m						
Earth	The diameter of grounding wire shall not be less than that of L, N terminal of the power. (When many PLCs are in use at the same time, please make sure every PLC is properly grounded.)						
Operation/storage	Operation: 0ºC ~ 55ºC (temperature); 50 ~ 95% (humidity); pollution degree 2 Storage: -40 ºC ~ 70 ºC (temperature); 5 ~ 95% (humidity)						
Vibration/shock immunity	International standards: IEC1131-2, IEC 68-2-6 (TEST Fc)/IEC1131-2 & IEC 68-2-27 (TEST Ea)						
Weight (g)	500/480	520/500	652/612	710/675	748/688	836/756	948/848

❖ Input point specifications

Items \ Spec.		24VDC single common port input		Note
		Low speed	High speed (200KHz)	
Input wiring type		Change wiring from S/S to SINK or SOURCE		Input point X0 ~ X7, X10 ~ X17 can conduct 10 ~ 60ms digital filter adjustment
Input indicator		LED display; light on = ON, light off = OFF		
Input voltage		24VDC ± 10%		
Active Level	Off→On	16VDC ± 10%		
	On→Off	12VDC ± 10%		
Response Time / Noise Immunity		10 ms	0.5us	

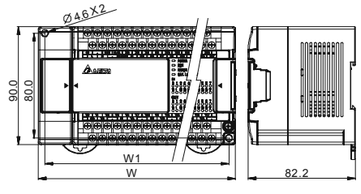
❖ Output point specifications

Items \ Spec.		Single common port transistor output		Single common port relay output
		Low speed	High speed*	
Max. frequency		10KHz	200KHz	Load ON/OFF control
Output indicator		LED display; light on = ON, light off = OFF		
Min. load		-		2mA/DC power supply
Working voltage		5 ~ 30VDC		＜250VAC, 30VDC
Insulation		Photocoupler isolation		Magnetic isolation
Current specification		0.3A/1 point @ 40ºC	<1KHz, 0.3A/1 point @ 40°C ≧1KHz, 30mA/1 point @ 40°C	2A/1 point (5A/COM) 75 VA (conductive), 90W (resistive)
Max. output delay time	Off→On	20us	0.2us	10ms
	On→Off	30us		
Over-current protection		N/A		
Mechanical life		N/A		2×10^7 times (without load)
Electrical life		N/A		1.5×10^5 times (5A 30VDC); 5×10^5 times (3A 120VAC); 3×10^4 times (5A 250VAC)

**High-speed output points (Y0, Y2) are only in DVP20EH2 and DVP32EH2; high-speed output points (Y0, Y1, Y2, Y3, Y4, Y6) are only in DVP40EH2.*

❸ Installation & Wiring

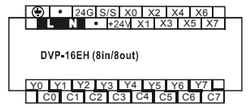
3.1 Dimension



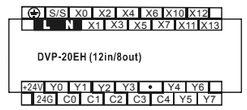
Model	W (mm)	W1 (mm)
DVP16EH00R2/T2	113	103
DVP20EH00R2/T2	113	103
DVP32EH00R2/T2	143.5	133.5
DVP40EH00R2/T2	158.8	153.8
DVP48EH00R2/T2	174	164
DVP64EH00R2/T2	212	202
DVP80EH00R2/T2	276	266

3.2 Wiring terminals

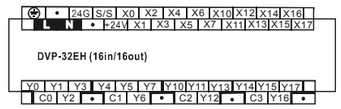
16EH2



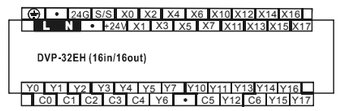
20EH2



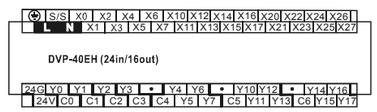
32EH2 *Relay*



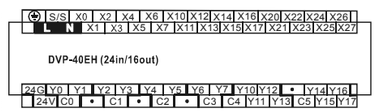
32EH2 *Transistor*



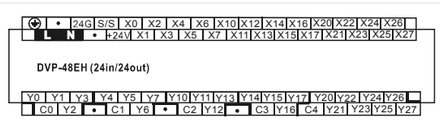
40EH2 *Relay*



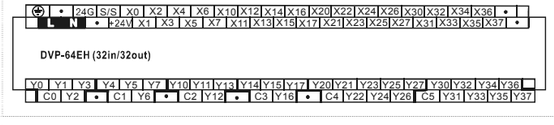
40EH2 *Transistor*



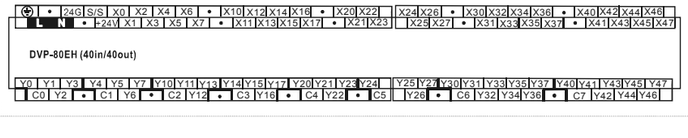
48EH2



64EH2



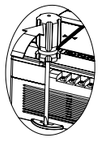
80EH2



3.3 Installation

❖ How to install DIN rail

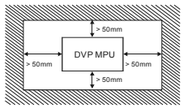
DVP-PLC can be secured to a cabinet by using the DIN rail of 35mm in height and 7.5mm in depth. When mounting PLC to DIN rail, be sure to use the end bracket to stop any side-to-side movement of PLC and reduce the chance of wires being loosen. A small retaining clip is at the bottom of PLC. To secure PLC to DIN rail, place the clip onto the rail and gently push it up. To remove it, pull the retaining clip down and gently remove PLC from DIN rail, as shown in the figure.



❖ How to screw

Please use M4 screw according to the dimension of the product.

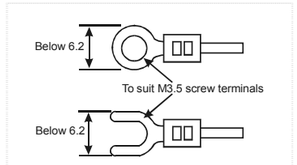
❖ Please install PLC in an enclosure with sufficient space around it to allow heat dissipation as shown in the figure.



3.4 Wiring

Please note that:

1. Use O-type or Y-type terminal. See the figure in the right for its specification. PLC terminal screws should be tightened to 5 ~ 8 kg-cm (4.3 ~ 6.9 in-lbs) and please use only 60/75 ºC copper conductor.
2. DO NOT wire empty terminal ⊡
3. DO NOT drop tiny metallic conductor into the PLC while screwing and wiring. Tear off the sticker on the heat dissipation hole for preventing alien substances from dropping in, to ensure normal heat dissipation of the PLC.

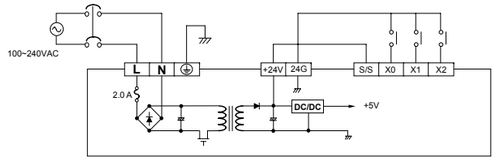


3.5 Power input wiring

The power input of DVP-EH2 series is AC. When operating the PLC, please make sure that:

1. The input voltage should be current and its range should be 100VAC ~ 240VAC. The power should be connected to L and N terminals. Wiring AC110V or AC220V to +24V terminal or input terminal will result in serious damage on the PLC.
2. The AC power input for PLC MPU and I/O extension modules should be ON or OFF at the same time.
3. Use wires of 1.6mm (or longer) for the grounding of PLC MPU.
4. The power shutdown of less than 10 ms will not affect the operation of the PLC. However, power shutdown time that is too long or the drop of power voltage will stop the operation of the PLC and all outputs will go OFF. When the power supply turns normal again, the PLC will automatically return to its operation. Please be aware of the latched auxiliary relays and registers inside the PLC when programming.

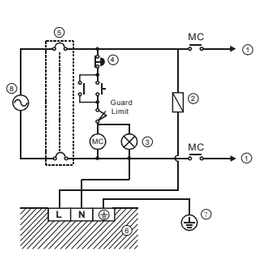
AC Power Input



0.5A is the maximum power supply for +24V power supply output terminal. DO NOT connect other external power supplies to this terminal. Every input terminal requires 6 ~ 7mA to be driven; e.g. the 16-point input will require approximately 100mA. Therefore, +24V cannot give output to external load that is more than 400mA.

3.6 Safety wiring

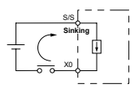
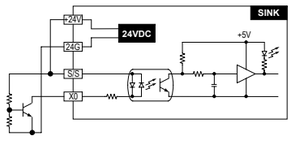
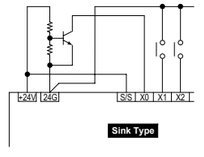
Since a PLC controls many devices, actions of any device may affect actions of other devices and the breakdown of any one device may cause the breakdown of the whole auto-control system and danger. Therefore, we suggest you wire a protection circuit at the power input terminal, as shown in the figure below.

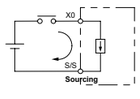
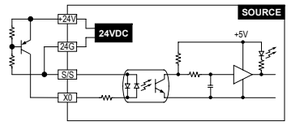
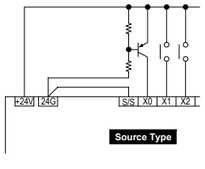


① AC power supply load
② Power circuit protection fuse (3A)
③ Power indicator
④ Emergency stop
This button can cut off the system power supply when accidental emergency takes place.
⑤ System circuit isolation device
The device is made of electromagnetic contactor and relay as the switch to prevent the instability of system when the power is intermittently supplied.
⑥ DVP-PLC (main processing unit)
⑦ Earth
⑧ Power supply
AC: 100 ~ 240VAC, 50/60Hz

3.7 Input point wiring

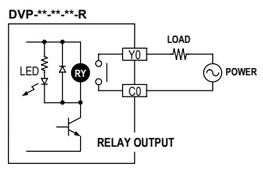
There are two types of DC inputs, SINK and SOURCE.

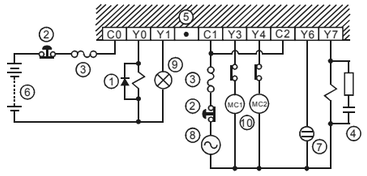
DC Signal IN	Input point loop equivalent circuit	Wiring loop
		
SINK mode (common port for current input S/S)		

DC Signal IN	Input point loop equivalent circuit	Wiring loop
		
SOURCE mode (common port for current output S/S)		

3.8 Output point wiring

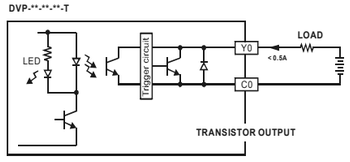
❖ **Relay (R) contact circuit wiring**

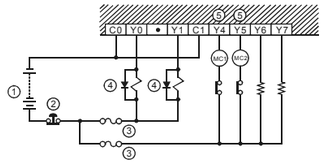




① Flywheel diode: To extend the life span of contact
② Emergency stop: Uses external switch
③ Fuse: Uses 5 ~ 10A fuse at the common port of output contacts to protect the output circuit.
④ Varistor: To reduce the interference on AC load
⑤ Empty terminal: not in use
⑥ DC power supply
⑦ Neon indicator
⑧ AC power supply
⑨ Incandescent light (resistive load)
⑩ Manually exclusive output: Uses external circuit and forms an interlock, together with the PLC internal program, to ensure safety protection in case of any unexpected errors.

❖ **Transistor (T) contact circuit wiring**





① DC power supply
② Emergency stop
③ Circuit protection fuse
④ Flywheel diode + inductive load
⑤ Manually exclusive output: Uses external circuit and forms an interlock, together with the PLC internal program, to ensure safety protection in case of any unexpected errors.

❹ Trial Operation

❖ **Power indication**

The “POWER” LED indicator on the front panel of PLC MPU (or extension module) will be on (in green) when the MPU is powered. That the MPU is powered but the indicator is not on indicates that the 24VDC power supply of the PLC is overloaded. You have to remove the wiring at terminal +24V and 24G and have another DC24V power supply ready. That the “ERROR” LED indicator flashes continuously indicates that the +24V power supply for the PLC is insufficient.

❖ **Low voltage indication**

That the “LOW.V” indicator on the front panel of the PLC extension module is on indicates that the input voltage is insufficient. All outputs of the module are disabled at this time.

❖ **Preparation**

1. Before powering DVP-EH2, be sure that you have checked if the I/O wiring is correct. You may damage the PLC if AC110V or AC220V is directly supplied to input terminals or the output wiring is short-circuited.
2. When the peripheral devices are used to write program into PLC: If the ERROR indicator does not flash, the program you are using is legal and PLC is waiting for RUN instruction from you.
3. You can use HPP to test “force On/Off” of output contacts.

❖ **Operation & test**

1. If the ERROR indicator does not flash, you can use RUN/STOP switch or peripheral device (HPP or WPLSoft) to give RUN instruction and the RUN indicator should be continuously on at this time. That the RUN indicator does not flash indicates PLC has no program in it.
2. When PLC is in operation, use HPP or WPLSoft to monitor the set value or temporarily saved value in the timer, counter, and register and force On/Off of output contacts. That the ERROR indicator is on (not flashes) indicates that part of the program exceeds the preset time-out. In this case, you have to check the program and set On/Off of the power again (PLC automatically returns to STOP status at this time).

❖ **I/O response time**

How to calculate the response time from the input signal to output operation of the PLC:

Response time = input delay time + program scan time (executed by the user) + output delay time

Input delay time	10ms (default); 0 ~ 60ms (adjustable). See the reference on how to use special register D1020 ~ D1021.
Program scan time	See the reference on how to use special register D1010.
Output delay time	Approx. 10ms for relay modules, 20 ~ 30us for transistor modules

❺ How to identify abnormality of PLC

To identify abnormality from the indicators on the panel, please check:

❖ **POWER indicator**

When PLC is powered, the POWER indicator on the front panel will be on (in green). If this indicator is not on when the PLC is powered, remove the wiring of +24V terminal. If this indicator turns on at this time, the +24V DC output is overloaded. In this case, DO NOT use DC power supply at +24V terminal and have another DC24V power supply ready. If this indicator turns off after the overload is eliminated, your PLC is malfunctioned. Send your PLC back to your distributor for repair.

❖ **RUN indicator**

Check your PLC status. When PLC is running, this indicator will be on. You can use HPP, the ladder diagram editing program or the switch on the panel to RUN or STOP PLC.

❖ **ERROR indicator**

1. If you enter illegal program into PLC or use instructions or devices that exceed their range, this indicator will flash (approx. every 1 sec.). When this happens, you have to obtain the error code from D1004 and save the address where the error occurs in register D1137 (if the error is a general circuit error, the address of D1137 will be invalid). Find out the cause of the error, amend the program and resend the program to PLC. If you cannot connect to PLC and this indicator keeps flashing quickly (approx. every 0.2 sec.), there should be insufficient 24VDC power supply. Please check if the 24VCD is overloaded.

   ❶ *For details of error codes (in D1004, hex coding), see “DVP-PLC Application Manual: Programming”*

2. If the ERROR indicator keeps flashing, you have to check the special relay M1008. M1008 is on indicates that the execution time of program loop exceeds the preset time-out (in D1000). In this case, turn the RUN/STOP switch to STOP, check the special register D1008 and obtain the location in the program where the time-out takes place. We suggest you use WDT instruction to correct this problem.

❖ **BAT.LOW indicator**

BAT.LOW indicator will be on when the battery is in low voltage. When this happens, change the battery as soon as possible in case your program and data saved in the latched area will be lost.

❶ *The changing of battery has to be completed within 1 minute when the PLC is not powered in order to save your procedures and data in the PLC.*

After the power is switched off, the data in the latched area are stored in SRAM memory and its power is supplied by the battery. Therefore, when the battery is in low voltage and the power-off has been lasted for more than 1 minute, the data in the latched area will be lost. If you need to permanently save the data in the latched area in the program and device D, refer to “Flash ROM permanently saved and recover mechanism” as stated below.

Permanently saved mechanism

You can use WPLSoft (Options -> PLC<=>Flash) to indicate whether to permanently store the data in the latched area in Flash ROM memory (new indicated data will replace all data previously saved in the memory).

Recover mechanism

If the battery is in low voltage (before the power is switched off when the BAT.LOW indicator is on) and the power is off for more than 1 minute, PLC will automatically restore the data in the latched area in the program and device D of Flash ROM into SRAM memory next time when it is re-powered.

Battery life:

Temperature (ºC)	0	25	50	70
Life (year)	9	8	6	5

❖ **Input indicator**

On/Off of input point is indicated by input indicator or monitored by HPP. When the action criteria of the input point are true, this indicator will be on. If abnormality is identified, check if the indicator and input circuit are normal.

❖ **Output indicator**

On/Off of output point is indicated by output indicator. When the output indicator (On/Off) does not correspond to the action of its load, please be aware of the follows:

1. The output contact may be melted or blocked out of overloading or short-circuited load, which will result in poor contact.
2. If you are suspicious that the output point may execute undesired action, check the output wiring circuit and whether the screw is properly tightened.

❖ **Accuracy (month/second) of RTC**

Temperature (°C/ºF)	0/32	25/77	55/131
Max. inaccuracy (second)	-117	52	-132

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